

Final Project Report



ESDplus

Integrating learning with geoinformation for a digitized and spatially enabled education for sustainable development

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Abstract

Education for Sustainable Development (ESD) is an ambitious issue, where ecological, economic, and socio-cultural aspects are discussed, negotiated and implemented. The aim is to motivate and empower learners to change their behavior in order to act in the spirit of sustainable development through the acquisition of new knowledge, skills and attitudes. For effective and contemporary learning, ESD strives to develop innovative methods and approaches. With societal changes like digitalization, this requires far-reaching changes in the way ESD is practiced, including the use of information and communication technologies and digital geomedial.

For further development of ESD, especially the use of digital geomedial (e.g., spatial data, methods, services, tools) opens new possibilities. Literature highlights that digital geomedial can promote new vitality in teaching and education, including ESD. But, digital geomedial use in ESD faces several challenges: There is a need for suitable teaching materials. As ESD addresses different audiences, this does not only refer to materials per se, but to materials that enable educators to respond to the different knowledge, skills and needs of learners when carrying out ESD activities. Further, ESD-educators typically lack the relevant spatial skills to use digital geomedial in ESD. One reason is that this is neither a core item in teacher nor in ESD-educator training. As a result, several questions remain regarding how to enhance the use of digital geomedial in ESD and support its further development: How can the need for teaching and training materials be addressed? What content do educators require in terms of teaching and training materials to effectively engage diverse types of learners? What should materials look like regarding design, structure, and delivery characteristics?

However, to improve ESD and to answer these questions, UNESCO MAB biosphere reserves are key: They are required to continuously develop and strengthen their role as innovative and holistic places for ESD and serve as sites for testing interdisciplinary approaches to understand and manage changes and interactions between social and ecological systems.

Now to answer the above questions, the project ESDplus aimed at developing online ESD-educator-centered teaching and training materials and modules to support ESD-educators in using digital geomedial in ESD. Through collaboration with two UNESCO MAB biosphere reserves (Lungau and Berchtesgader Land) and numerous ESD-educators in the context of a specially developed workflow, requirements and recommendations for the implementation of educator-centered products regarding content, structure, design, and delivery mode were specified. The key requirement for products is the target integration of digital geomedial in ESD (i.e., always putting ESD and practice first). Further awareness rising, building interest and motivation are key. This requires comprehensive information work – which is supported by additional resources in ESDplus, such as especially a collection of application examples regarding digital geomedial use in ESD and community building.

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1 Introduction and research questions

Education for Sustainable Development (ESD) is an ambitious initiative that discusses, negotiates, and implements ecological, economic, and socio-cultural aspects (Kruse-Graumann 2007). It promotes the integration of sustainable development topics such as climate change, disaster risk reduction, biodiversity, and sustainable consumption, alongside the United Nations Sustainable Development Goals (UN SDGs), which include good health and well-being, no poverty, as well as affordable and clean energy, into teaching and learning. The aim of ESD is to motivate and empower learners to change their behavior by acquiring new knowledge, skills, attitudes, and values necessary for creating a sustainable future and sustainable development (UNESCO 2017). To achieve this, ESD employs a wide variety of methods and concepts (e.g., participatory learning, active learning, experiential learning) and strives to develop and apply innovative teaching and learning approaches (UNESCO 2013, 2017).

In light of societal changes, such as digitalization accelerated by the COVID-19 pandemic (Dhawan 2020; Zancajo et al. 2022), ESD also requires changes in the way it is conducted (UNESCO 2013, 2017). As in education per se, this includes the integration of Information and Communication Technologies (ICT) and particularly of digital geomedial, which presents new possibilities for ESD (Fauville et al. 2013; Hennig 2006; Hennig 2015; Lude et al. 2013; Referowska-Chodak 2020).

Digital geomedial refer to the digital transformation of cartography in the context of information communication (Traun et al. 2013). This shift moves from traditional representations of spatial information, such as conventional maps, to interactive platforms that link users and information in an interactive way through location-based interfaces, exemplified by using location as an interface. According to Diamond (2015), digital geomedial encompass open data, including volunteered geographic information, and open-source spatial methods and tools. In (school) education, examples include location-based games like Geocaching and ActionBound, web mapping tools such as Google Maps and Scribble Maps, virtual globes like Google Earth, data capture apps such as GPS Essentials and ArcGIS QuickCapture, and data visualization tools like interactive maps, story maps, and dashboards. Overall, digital geomedial offer a wide array of options for analyzing, presenting, and visualizing information, i.e., spatial data, enabling users to become informed, collect and exchange information, and connect and network (Gryl et al. 2012; Thielmann et al. 2012).

The use of digital geomedial brings several benefits for both formal and non-formal education. In addition to motivational effects, this refers to the improvement of learning and communication through the spatial contextualization of content (Passey et al. 2004; Vogler et al. 2018). It offers new and engaging insights into the topic under consideration (including Sustainable Development Goals), not only by spatialization, but also by fostering the learners' active engagement through "learning by doing" (BMBWF n.d.; Vogler et al. 2018). This aligns with the development of digital and spatial competencies among learners. These skills, which are also stressed by the concepts of spatial thinking and spatial citizenship (Gryl et al. 2012; NRC 2006), encompass technical and methodological competencies, reflective abilities, and the capacity for active communication and participation using digital geomedial. Further, spatial skills are related to competencies relevant for sustainable development, such as social and civic engagement, critical thinking and collaborative decision-making (Bertschy et al. 2017; Gonzales 2014; UNESCO 2017). Ultimately, the use of digital geomedial helps to strengthen learners' interest and knowledge, increase their autonomy, better prepare them for future challenges, involve them in public participation and decision-making, and motivate them to contribute to sustainable development (ALPARC n.d.; Gryl & Jekel 2018).

Apart from its benefits, the use of digital geomedial in education faces several challenges. Educators must possess specific knowledge and competencies to effectively use digital geomedial. Without this expertise, digital geomedial use can become a burden, as educators struggle with software usage and

technical issues (Li et al. 2022; Vogler & Hennig 2022). As a result, educators may reject the use of digital geomedia (Lindner-Fally & Zwartes 2012). Further, digital geomedia use is not a core focus in teacher training or ESD-educator training (ANUOe 2022; Lindner-Fally & Zwartes 2012). When attention is given to digital geomedia use, it very often centers on topics such as location-based games (e.g., Geocaching; Baier et al. 2016) and digital rallies (Hiller et al. 2019). Additionally, there is a lack of initiatives that provide ESD-educators with an overview of existing resources and possibilities. This includes teaching materials whose content and activities (including data, methods, and tools) are tailored to the knowledge, abilities, and skills of the learners and address different levels of complexity. As a result, here are open questions about how the use of digital geomedia in ESD can be improved and how its further development can be supported:

- (i) How can the need for teaching and training materials be (better) addressed?
- (ii) What content do ESD-educators require in terms of teaching and training materials to effectively engage diverse types of learners?
- (iii) What should teaching and training materials look like regarding design, structure, and delivery characteristics?

Within the framework of the ESDplus project, these questions were addressed, among other things, through the development of two teaching modules (Box 1.1) and one training module, including associated materials. The ESDplus products, which support ESD-educators and others interested in using digital geomedia in ESD are available online as open-access resources, i.e., as Open Education Resources (OER) under Creative Commons Licence (CC-BY-NC-ND 4.0; <https://esdplus-zgis.hub.arcgis.com/pages/61427d7271764bc291e3e609a9f70593>).

Box 1.1: ESDplus teaching modules (considering information from Bonney et al. 2009; Fischer et al. 2021; GEO n.d.; Haklay 2021; Kermish-Allen et al. 2017; Land-Zandstra et al. 2021; Læssøe 2010; Shirk et al. 2012; Sykas 2019)

The two ESDplus pilot teaching modules focus on Geo Citizen Science (GCS) and Earth Observation (EO). Both topics are particularly useful for addressing issues related to ESD. For instance, EO is considered an important aspect for achieving the UN Sustainable Development Goals (SDG), since it utilizes satellite, airborne, and in-situ sensors to provide accurate and reliable information on the state of the atmosphere, oceans, coasts, rivers, soil, crops, forests, ecosystems, natural resources, ice, snow, and built infrastructure, including their changes over time. GCS emphasizes that participation is a key concept in democratically oriented Education for Sustainable Development (ESD). Among the various forms of citizen science (e.g., consultatory, contributory, collaborative, and co-created), data contribution projects are the most common ones. With (spatial) data collection methods such as passive sensing, crowdsourcing, environmental observations, and participatory sensing, contributory initiatives offer numerous opportunities for learners to engage with ecological, economic, and socio-cultural aspects, as well as the interaction between natural and socio-economic processes.

The ESDplus product development depends on collaborating with two biosphere reserves (BRs): the Biosphere Park Lungau (Austria) and the Biosphere Region Berchtesgader Land (Germany). UNESCO MAB biosphere reserves play a key role for ESD, i.e., for the advancement and strengthening of ESD (Box 1.2). In addition to these UNESCO BRs, project partners include the Department of Sociology & Social Geography/ School of Education PLUS, GI_PLUS, Uni 55-PLUS, and PH Salzburg.

Box 1.2: UNESCO MAB biosphere reserves and ESD (Gower et al. 2022; UNESCO 2017, 2020a, 2021)

UNESCO MAB biosphere reserves (BRs) serve as model regions for and learning places for sustainable development. The provision of educational activities in BRs is guided by “Education for Sustainable Development: Towards achieving the SDGs (ESD for 2030)”, a UNESCO-endorsed education program. Furthermore, the Lima Action Plan highlights measures to ensure effective implementation of the MAB Strategy 2015-2025, with a particular focus on promoting biosphere reserves in education. Here, BRs are expected to continuously develop and strengthen their role as innovative and holistic places for ESD. They serve as sites for testing interdisciplinary approaches to understand and manage the changes and interactions between social and ecological systems, including conflict prevention and management regarding biodiversity. Through their coordinators, managers, and scientists, BRs play a significant role in operationalizing and mainstreaming sustainability science and ESD at local and regional levels. They build scientific knowledge, identify best practices, and strengthen the interface between science, policy, education, and training for sustainable development. The basis for this are their partnerships with local (formal and non-formal) education providers, research institutions, and universities, which facilitate interaction between practice and research, including ESD. As a result, BRs are considered hubs from which new ESD approaches and innovations can be disseminated.

In the following sections, we first present the concepts, approaches and methods as well as the workflow that were used for the development of the user-centered ESDplus products (section 2). Section 3 describes selected results of an online survey among ESD-educators in the DACH region, which was conducted to learn more about the current use of digital geomedial in ESD and to identify the related needs of ESD-educators. Building on these findings and the results of the other methods applied (e.g. literature review, analysis of similar systems AoSS), section 4 outlines the requirements of ESD-educators regarding the use of digital geomedial in ESD and provides recommendations for addressing them. This section also includes insights into the final design and implementation of the ESDplus products, such as the teaching and training modules and materials. Finally, in section 5 we discuss the ESDplus products and the underlying workflow in the context of their additional benefits for ESD per se. This includes providing practical and theoretical foundations as well as support in building a corresponding community. Section 6 delivers conclusions and an outlook regarding the ESDplus project and its findings.

2 Workflow and Methods

To deliver ESD-educator-centered products, a project-specific workflow was created and implemented. This development process is based on the main tasks of application development (i.e., requirements specification, design, implementation, and testing with optimization; Sommerville 2012) and considers aspects from different design approaches and process models. By using appropriate methods, this enables the active participation of ESD-educators, i.e. the target group, in the development of ESDplus materials and modules. As shown in Figure 2.1, the ESDplus workflow consists of four steps. The design approaches, process models, as well as methods and tools used are described in more detail below, along with the transdisciplinary team involved in the development process. Further information on this specially developed workflow can be found in Hennig et al. (2024a).

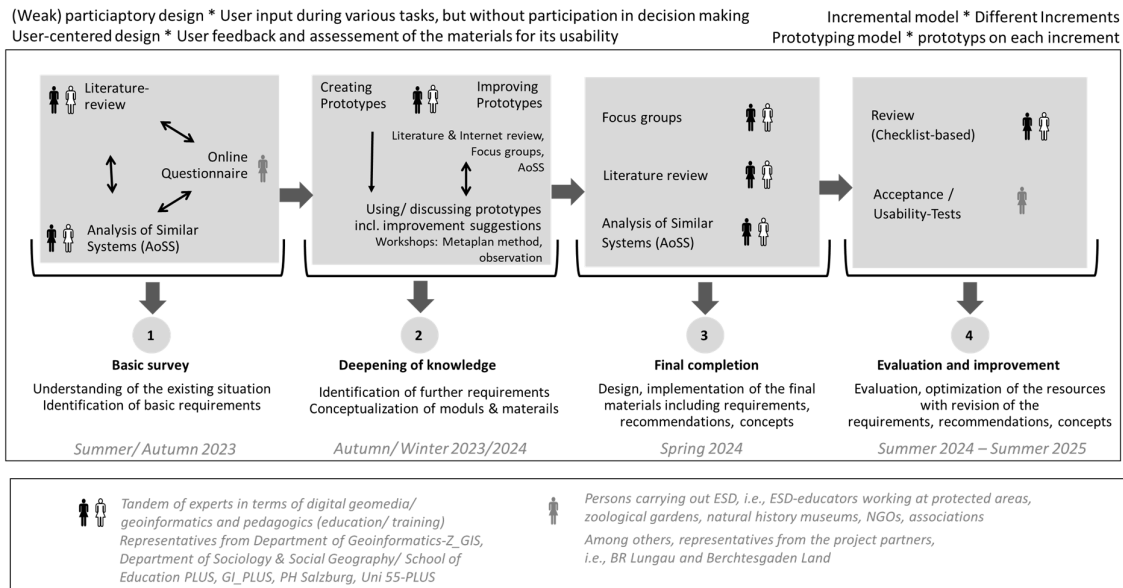


Figure 2.1: Schematic ESDplus workflow including aspects regarding design approaches and process models, as well as methods and tools used and outlining tasks and roles of the ESDplus partners (adapted from Hennig et al. 2024a)

2.1 Design approaches

Design approaches place future users at the center of a development process, allowing for varying degrees and levels of involvement. Examples of approaches related to human-computer interaction are participatory design and user-centered design (Baek et al. 2007; Mithun et al. 2018; Wilkinson et al. 2014). Both are briefly described in Table 2.1. As illustrated in Figure 2.1, the ESDplus development process is guided by specific elements of participatory design, namely direct and active user involvement (i.e., weak participatory design) and user-centered design.

Table 2.1: Examples of design approaches (Baek et al. 2007; Hennig et al. 2024a; Kensing & Blomberg 1998; Mithun et al. 2018)

Design approaches	Description
Participatory design	- designing-with rather than designing-for users, i.e., the target group - future users actively and directly take part in activities of an ongoing development process - distinction between strong and weak participatory design: in strong participatory design, representatives of the target group are involved throughout the entire development process, including decision-making; in weak participatory design, input is obtained from the future users, but decisions are made exclusively by the experts and/or developers
User-centered design	- focus on early and repeated user feedback during product design and implementation - enabling iterative refinement of requirements specification, design and implementation - making use of several methods that allow users to assess a product for its usability

2.2 Process models

As already mentioned, development processes usually encompass requirements specification, design and implementation, as well as testing with optimization. The focus and sequence of these tasks can vary depending on the process model employed. Each model organizes the activities of requirements specification, design, implementation, and testing into different phases, which are arranged differently and have different levels of importance depending on the model (Pressman et al. 2019; Sommerville

2012). Examples of process models include the prototyping model and the incremental model (Table 2.2).

Table 2.2: Examples of process models (Agarwal et al. 2010; Hennig et al. 2024a; Kumar 2021; Stoica et al. 2013; West & Pateman 2016)

Process models	Description
Prototyping model	• characterized by its iterative nature: starting from an initial specification, the requirements directed towards a product are continuously and further identified and improved until all stakeholders (including users) are satisfied • based on several loops in which specially developed prototypes are discussed and optimized according to the feedback received • leads to comprehensive requirements learning and final user requirements specification, which form the basis for the design, implementation, and testing of the ultimate final product
Incremental model	• based on the initial known requirements, different product subsets are identified so that standalone increments can be developed, considering the respective requirements • development of each increment encompasses requirements specification, design, implementation, and testing with optimization

The ESDplus development process is structured around the prototyping and the incremental model in terms of various aspects (Figure 2.1): Requirements are gathered and refined through the creation and discussion of different prototypes. The insights gained from the discussions with ESD-educators in the context of different workshops serve as the foundation for the further design and implementation of the final ESDplus modules and materials. As starting point, the ESDplus products, i.e., teaching and training modules, are divided into subsets, i.e. increments, that encompass different materials (Figure 2.2). For these increments, prototypes were realized, discussed, and optimized.

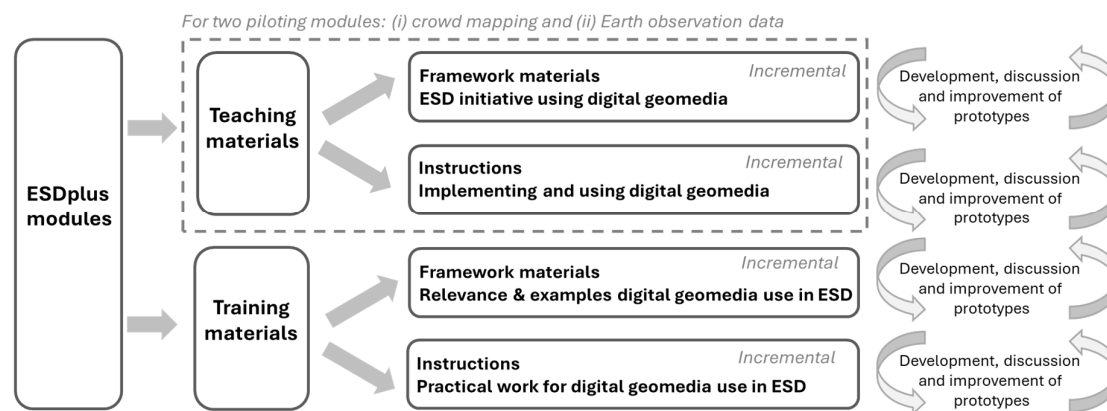


Figure 2.2: Increments for which module prototypes were realized (Hennig et al. 2024a)

2.3 Methods and tools

Within the ESDplus workflow, different methods were employed across the four development steps (Table 2.3). Their selection and combination is based on their potential to facilitate appropriate involvement of ESD-educators in the development process. The ESDplus products (e.g., teaching and training materials and modules) were implemented using various tools from the ESRI ecosystem, such as ArcGIS Hub, StoryMap Collection, and StoryMaps.

Table 2.3: Selected methods used throughout the ESDplus development process

Step	Method	Description and selected details
1	Literature review	literature on the use of digital geomedial in education (e.g., spatial citizenship, spatially enabled learning, learning with geoinformation and ESD)
	Online Questionnaire	14 open and closed questions (see Appendix, Table 1) using LimeSurvey (https://www.limesurvey.org/) - carried out: autumn and winter 2023/2024 - directed towards ESD organizations such as protected areas, natural history museums, zoological gardens, environmental stations, NGOs, and associations located in the DACH region (Germany, Austria, Switzerland) 83 valid responses
	Analysis of similar systems (AoSS)	- analysis of websites of organizations performing ESD (focusing on information regarding ESD activities using digital geomedial) - analysis of websites presenting/describing ESD activities using digital geomedial, e.g., Sustainicum (http://www.sustainicum.at/), BNEBOX (https://www.bne-box.lehrerbildung-at-lmu.mzl.lmu.de/), PlayGreen (https://www.play-green.net/), PublicClimateSchool (https://publicclimateschool.de), ESRI resources (https://www.esri.com/en-us/arcgis/products/arcgis-online/resources)
2	Focus Group Workshops	- preparatory focus group to discuss and decide GCS and EO module topics (i.e., mapping of meadow plants, and landscape changes), contents, and specifications - six workshops with between 6 to 10 participants each (see Appendix, Table 2) - use and discussion of prototypes of teaching and training modules and materials - meta-plan method to support the discussion of the prototypes and the provision of improvement suggestions - observation of participants working with the prototypes
3	Design, Implementation	- applying guidelines, methods, and tools for application design and implementation (among other things based on findings from step 1) - considering ESD-educators' requirements and related recommendations (based on findings from step 2)
4	Review/walk-through	joint review by developers and experts using particularly created checklists based on criteria from literature (https://esdplus-zgis.hub.arcgis.com/pages/9c49713944ac49b2b27dda329d6fcd28; see menu item Arbeitsmaterialien)
	Acceptance/usability tests	use of teaching modules and materials by representatives of the target group, i.e., ESD-educators, to develop and carry out their own ESD event, and in this context evaluate the ESDplus modules and materials

2.4 Transdisciplinary project team

In addition to the involvement of ESD-educators in the development process, who were recruited with the help and support of the BRs, the composition of the ESDplus project team is particularly noteworthy. The transdisciplinary project team included ESD-educators from the two UNESCO BRs (Lungau and Berchtesgadener Land), as well as experts in geoinformatics and digital geomedial as well as its educational use (Department of Geoinformatics-Z_GIS/ IDEAS:lab PLUS, GI_PLUS), and professionals in teacher training (Department of Sociology & Social Geography/ School of Education PLUS, PH Salzburg). This diverse array of backgrounds and perspectives was crucial in informing the development of materials and modules, and thus for the development of the ESDplus products (Hennig 2024a).

3 Survey results

The online questionnaire resulted in 83 responses, although 239 people accessed it. This is because in LimeSurvey responses are recorded only when participants actively submit the questionnaire by clicking the final “Submit” button. However, with a response rate of 6 %, this is still within an acceptable range, as also highlighted in the literature (e.g., Le Masson 2025). Selected findings are presented below. More details can be found in Hennig (2024a), Hennig et al. (2024a), Hennig et al. (2024b) and Hennig et al. (2024c).

The results indicate that about a quarter of the respondents have not yet used digital geomedial in ESD, and only 4 % use it extensively (Figure 3.1). This is underlined by the fact that 69 respondents prefer traditional (i.e., analog) geomedial in ESD, while 22 see digital geomedial use as only partially suitable for ESD (Figure 3.2). Nevertheless, 52 respondents recognize great potential in digital geomedial use for ESD; 33 outline that extensive training is necessary to be able to use digital geomedial in ESD appropriately.

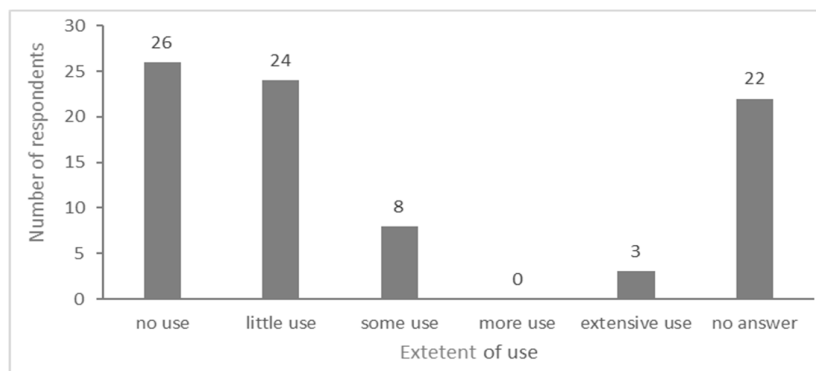


Figure 3.1: Extent of digital geomedial use in ESD organizations (N=83; single choice; absolute data; Hennig 2024b)

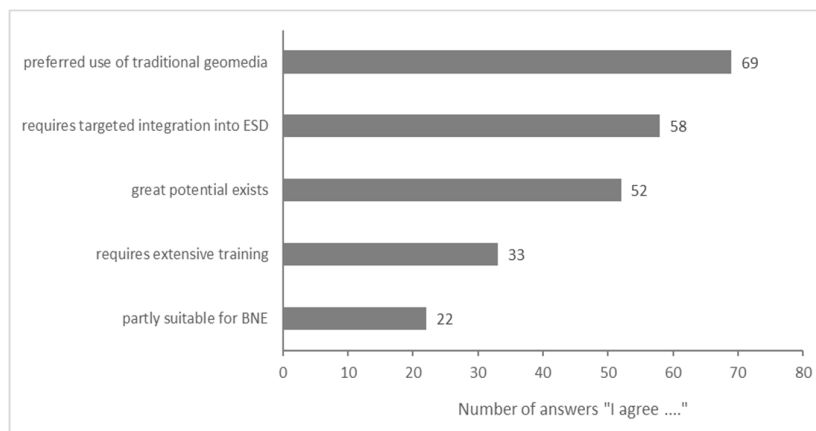
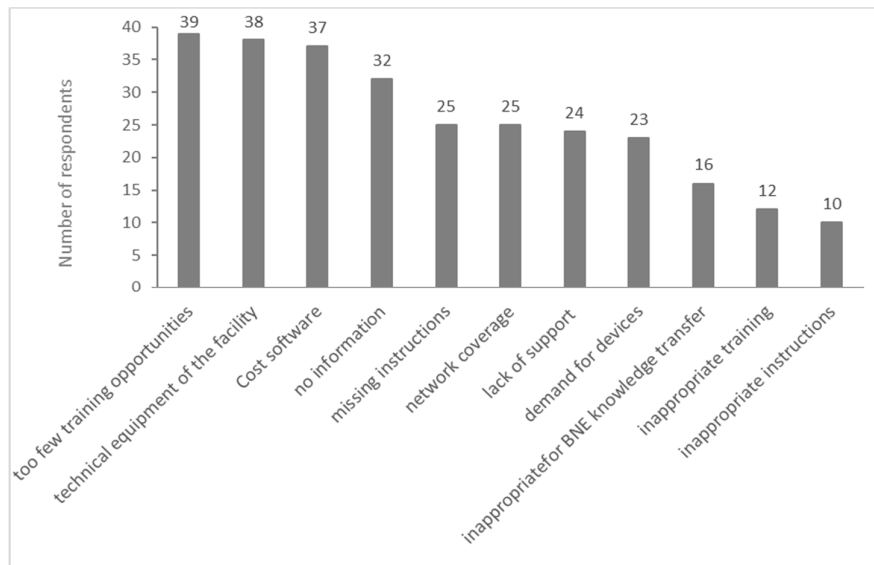


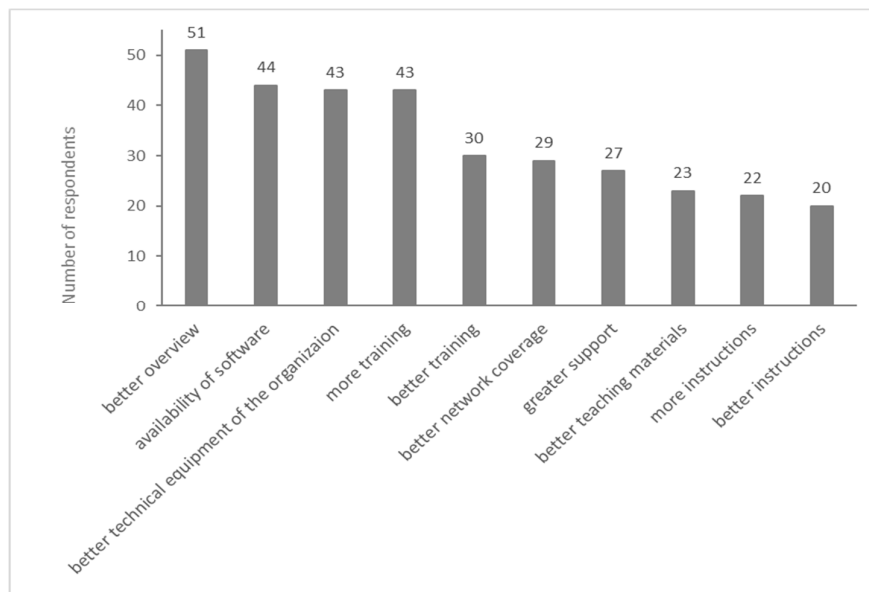
Figure 3.2: Agreement on selected aspects regarding digital geomedial use in ESD (N=83, multiple choice; absolute data; Hennig 2024b)

Regarding aspects that hamper digital geomedial use in ESD, the survey findings highlight that almost half of the ESD-educators questioned consider insufficient training (47 %), the technical equipment of the respective organizations (46 %), and the costs of software licenses (45 %) as barriers to the use of digital geomedial in ESD (Figure 3.3 a). Further, respondents emphasize the need for improvements in several areas to enhance digital geomedial use in ESD (Figure 3.3 b): a better overview of digital

geomedia (61 %), improved availability of software (53 %) and technical equipment within their organization (52 %), and more training opportunities (52 %).



(a)



(b)

Figure 3.3: Barriers (a) and possibilities to support (b) digital geomedia use in ESD (N=83, multiple choice; absolute data; Hennig 2024b)

Concerning knowledge and use of digital geomedia, Google Maps and Google Earth are known and used by most respondents (Figure 3.4). Results show that ESD-educators know and use Google Earth but not digital globes, even though Google Earth is a digital globe. This indicates a certain lack of understanding and knowing related concepts and terms on the part of ESD-educators. This is also stressed by Figure 3.5 and Figure 3.6, showing that basic aspects are more or less known while advanced aspects not.

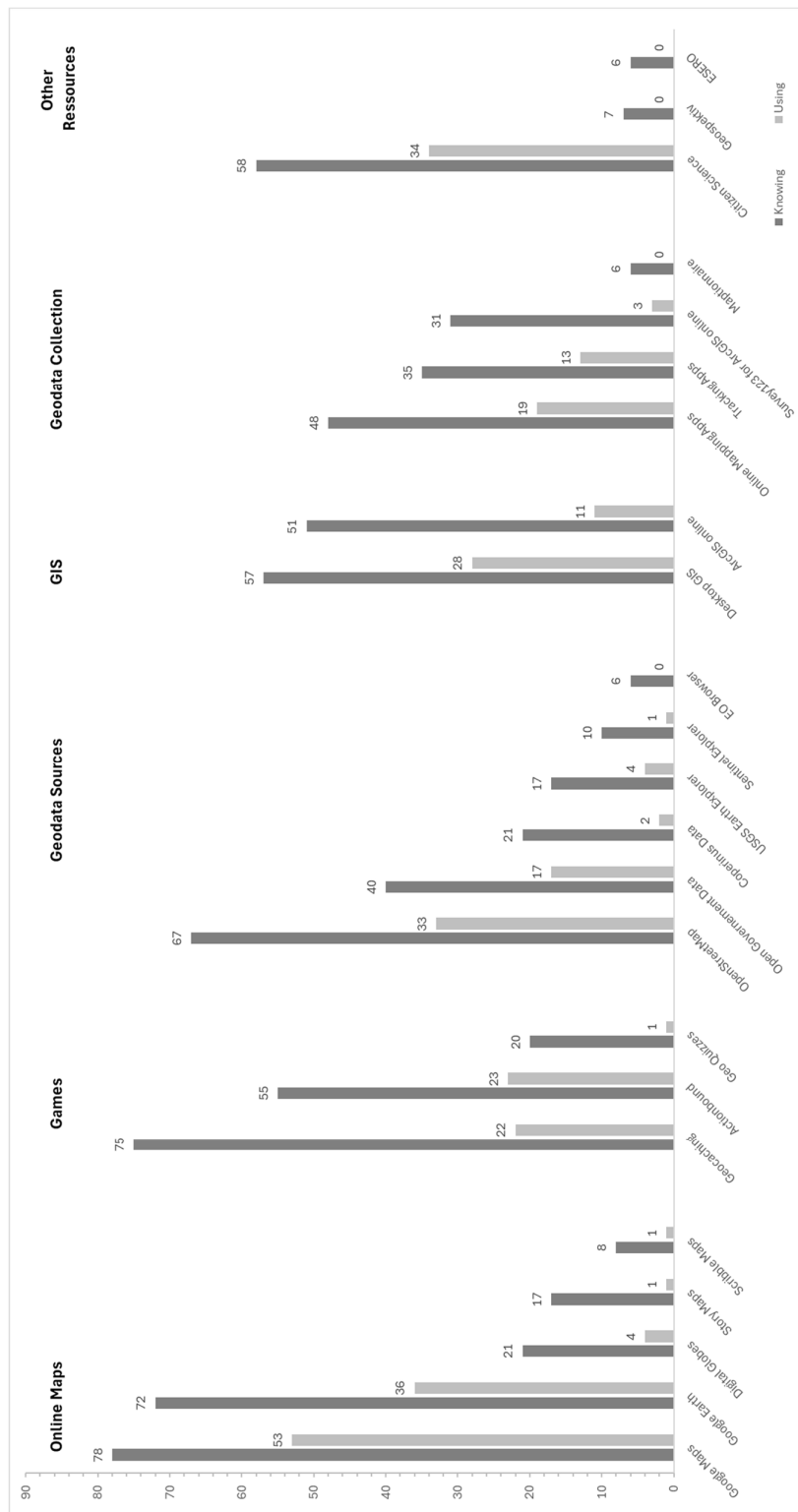


Figure 3.4: Knowledge and use of digital geomedias on part of the respondents (N=83, multiple choice question; absolute data)

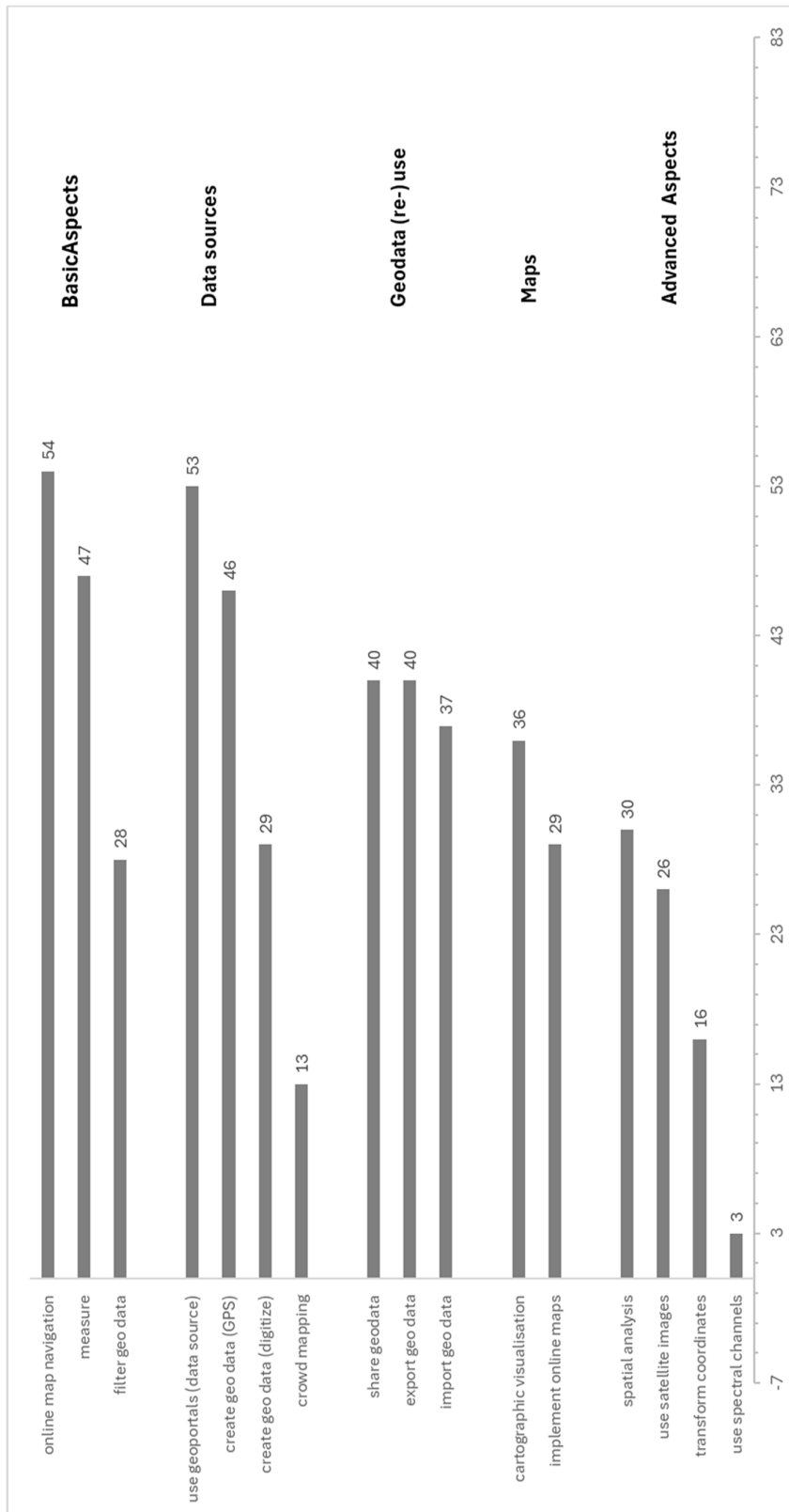


Figure 3.5: Activities performed on part of the respondents (absolute data, N=83, multiple choice question; absolute data)

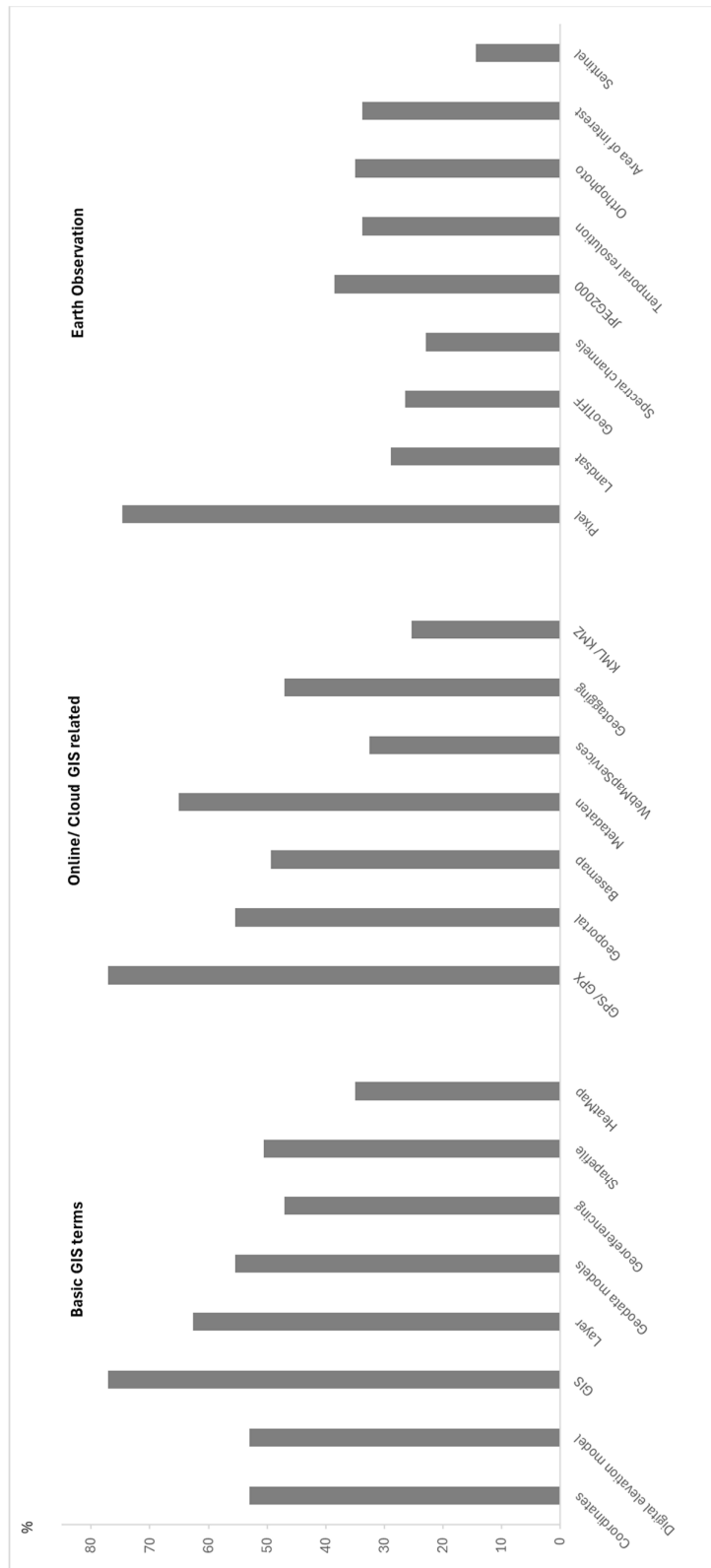


Figure 3.6: Knowledge of terms and concepts on part of the respondents (absolute data, N=83, multiple choice question; absolute data)

Overall, 28 respondents provided best practice examples, which include location-based games (e.g., Geocaching and ActionBound), online maps (e.g., Google Maps), virtual globes (e.g., Google Earth), geoportals (e.g., Open Government Data OGD), GPS-related tools and apps, and Citizen Science initiatives. Benefits were described by 59 % of respondents, highlighting advantages such as use of current data, an easy way to combine different information, and being a contemporary, interactive approach.

4 ESDplus products, including requirements and recommendations

Based on the findings from the online survey, workshops and test events as well as the results from the literature and internet research and AoSS, the ESDplus teaching and training materials and modules were supplemented with further products relevant for ESD-educators. This is an online collection of application examples for the use of digital geomedial in ESD and a glossary with terms and concepts for the basic use of digital geomedial (Figure 4.1; Table 4.1).

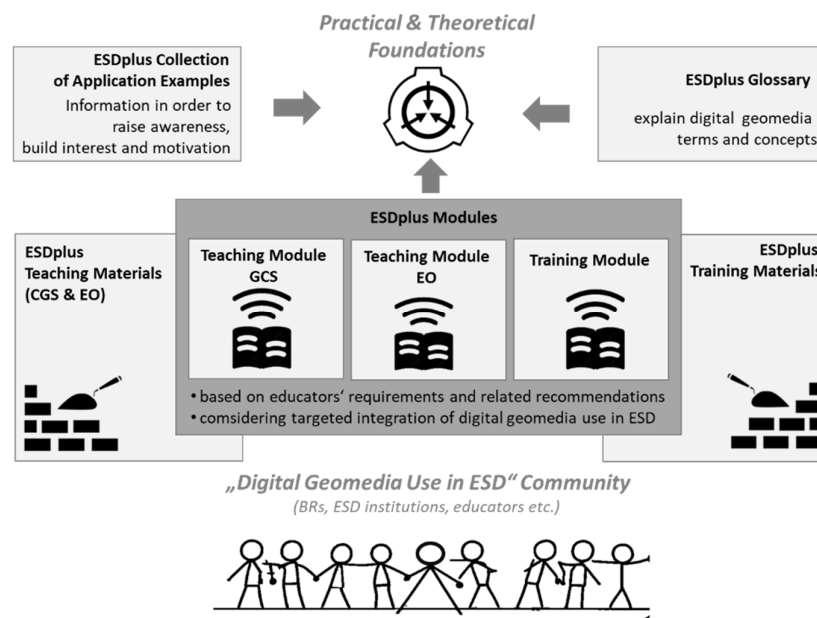


Figure 4.1: ESDplus products, including ESDplus requirements and related recommendations

Table 4.1: Overview of ESDplus products serving as a practical foundation to support digital geomedial use in ESD

ESDplus Product	Link
ESDplus Teaching Module GCS "Wiesenpflanzen unter Beobachtung"	https://wiesenpflanze-zgis.hub.arcgis.com/
ESDplus Teaching Module EO "Landnutzung aus der Vogelperspektive"	https://eo-landnutzung-zgis.hub.arcgis.com/
ESDplus Training Module	https://trainthetrainer-geomedien-zgis.hub.arcgis.com/
ESDplus Collection of application examples	https://esdplus-zgis.hub.arcgis.com/pages/a1f16b4f68e349a2832a98e3e3f0b5f1
ESDplus Glossary	https://storymaps.arcgis.com/stories/906b71b4118d4543bd59971636473d0f/

Although each of the ESDplus products has specific content, some requirements regarding design, structure and delivery mode, as well as recommendations for addressing the needs of ESD-educators, are the same and of equal importance for all products. Overall, these are key requirements for fulfilling and supporting the targeted integration of the use of digital geomedial into ESD.

4.1 Content and structure

4.1.1 ESDplus collection of application examples

The survey results show that digital geomedia are still rarely used in ESD (Figure 3.1) and if so, only with the use of a few aspects (Figure 3.4). Most respondents prefer analogue geomedia to digital geomedia and consider digital geomedia use in ESD to be less suitable than analogue methods (Figure 3.2; Figure 3.3). Against this background, there is a clear need for more information on digital geomedia use in ESD. To meet the information needs, application examples – including best practice examples – were collected and made available on the ESDplus website, i.e., portal.

This information provides a comprehensive overview of various categories of digital geomedia (Figure 4.2) and is inspired by information on the use of digital geomedia in formal education, specifically secondary education (e.g., Schmid 2018). It aligns with the need to present an overview of existing and potential uses of digital geomedia in ESD, including current application examples. These points are highlighted in the questionnaire results (Figure 3.2; Figure 3.3). The results of the workshop also underline this: Notably, during the workshops, ESD-educators emphasized the importance of showcasing application examples of digital geomedia use in ESD that are relevant and interesting to them and can be easily integrated and used in the context of their ESD activities, and illustrating their benefits within the specific context of ESD activities.

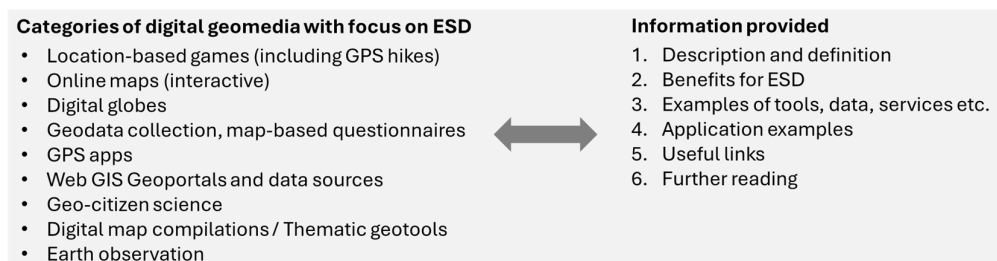


Figure 4.2: Addressing ESD-educators needs of information and overview: collection of application examples of digital geomedia use in ESD

The information provided for each category of digital geomedia addresses the general needs of ESD-educators. It contains descriptions and definitions, benefits for ESD, examples, useful links, and further reading (Figure 4.2). By presenting open-access tools and methods that are easy to install and use, the collection of application examples of digital geomedia helps to overcome some of the challenges stressed in the questionnaire, such as software availability, cost, and technical requirements (Figure 3.3). In addition to the focus on ESD, information from formal education is also integrated and ESD-educators have the opportunity to contribute examples of application that are familiar to them. This sharing of information meets with sustainability requirements in teaching (Muuß-Merholz 2020).

4.1.2 ESDplus teaching modules and materials

The ESDplus teaching modules contain module-specific teaching materials that guide ESD-educators in using digital geomedia in ESD. The modules are characterized by a particular content and structure.

Content

The results of AoSS, supported by insights from the online questionnaire and workshops with ESD-educators, show that ESD-educators need different types of information. This information can be categorized into five groups (Table 4.2): (i) background information, (ii) framework information, (iii) instructions, (iv) working materials, and (v) supportive information.

Table 4.2: Types of information required on the ESDplus teaching modules

Content	Detail
Background information	• introduction to the materials, including the philosophy behind the module and materials
Framework information	• information on how to design and implement a respective ESD initiative/ activity using digital geomeia • information on how to address the learners and the topic of the BNE activity based on using the ESDplus teaching modules and materials • technical requirements regarding hardware, software, Internet, etc. (to run the according BNE activity)
Instructions	• information and step-by-step guidelines on how to implement the according digital geomeia (i.e. tool) to be used in the respective ESD activity • showing possibilities for individualization • instructions are particularly suitable for laypeople in the use of geomeia
Working documents	• exemplary materials to support work with digital geomeia, e.g. to support analyzes based on key questions
Supportive information	• additional information that might be of interest for the use of the teaching modules and materials and the implementation of own ESD activities based on the teaching modules materials

The information provided takes into account several aspects that are particularly relevant for ESD-educators. These include, for instance, the following points from the literature (e.g., EU 2012; UNESCO 2013, 2017; ALPARC n.d.) as well as gained during the workshop:

- start information and materials by considering the current background and level of the learners, i.e., considering their existing knowledge and interests; this is in line with the idea that (adult) education based on learners' experiences, skills, and knowledge is more effective
- pursue an integrated approach that primarily addresses issues and skills of sustainable development, but also (addition) brings spatial skills (closer) to the learner
- enable ESD-educators to create their own ESD activities tailored to their needs, topics, and target groups, and that can also have a different duration from several hours to several days
- integrate interdisciplinary methods and approaches such as activity-, problem- and project-based approaches to better reach and engage learners
- consider different didactic methods that take into account the learners and their backgrounds and allow ESD-educators to adapt to the different levels of interest and complexity of the different target groups

Structure

ESD events generally consist of different activities such as activation, exploration, reflection, and facilitation (Waterson & Fang 2012). The same is true to educational initiatives that use digital geomeia. They are, for instance, divided into activities centered on spatial data provision/collection, visualization and analysis, interpretation, and discussion (ESRI 2022; Zorenböhmer et al. 2022). Building on this, the ESDplus teaching modules comprise different units (Table 4.3): (i) Welcome, (ii) Plan (defining the framework), (iii) Activate (engaging participants), (iv) Collect (providing the required data), (v) Analyze (analyzing data and/ or the according situation), (vi) Reflect (reflecting of the findings in the context of ESD objectives).

Table 4.3: Structure of ESDplus teaching modules including information, i.e., materials available in the context of the different units

Units	Teaching modules GCS	Teaching module EO
Welcome	• Background and more • Philosophy behind • Benefits of using digital geomedial in ESD • Relevant didactical concepts • Addressed SDG and ESD objectives • Overview of spatial skills, i.e. which skills are addressed in the context of the presented activity	
Plan	• Define the framework • Background on meadow plants • Units regarding this ESD activity • Overview: all materials at a glance • Checklist to support ESD-educators in creating their own activity • Background and more information on digital geomedial use in ESD and environmental education	• Define the framework • Background on landscape changes • Units regarding this ESD activity • Overview; all materials at a glance • Checklist to support ESD-educators in creating their own activity • Background and more information on digital geomedial use in ESD and environmental education
Activate	• Preparation “Activate” (with focus on meadow plants) • Run “Activate” (with focus on meadow plants) • Document presenting selected plants to map • Information on traditional ESD methods supporting “Activate”	• Preparation “Activate” (with focus on landscape change) • Run “Activate” (with focus on landscape change) • Information on traditional ESD methods supporting “Activate”
Collect	• Preparation “Collect” • Run “Collect” • Document to learn how to create a KoboToolbox account • Document on how to create a KoboToolbox mapping app • More information on creating a KoboToolbox mapping app • Document on how to use the KoboToolbox mapping app	• Preparation “Collect” • Run “Collect” • Document to learn image interpretation I • Document to learn image interpretation II
Analyze	• Preparation “Analyze” • Run “Analyze” • Document on how to create a KoboToolbox online map showing the mapped data • Document on how to use the KoboToolbox online map • Document to support data analysis using the KoboToolbox online map (selected key questions)	• Preparation “Analyze” • Run “Analyze” • Document regarding building interest in the topic • Document to learn how to digitize changes using Google Earth • Document to support data analysis using Google Earth (selected key questions)
Reflect	• Preparation “Reflect” • Run “Reflect” • Information on the use of traditional ESD methods supporting “Reflect” • Possibility for Feedback	

Taking this into account (Table 4.2; Table 4.3), a structure was developed that consists of three areas (Figure 4.3): (i) a menu for selecting a unit (i.e., Welcome, Activate, Collect, Analyze, Reflect), (ii) an area with a brief explanation of the respective unit, and (iii) a material-box containing all information and materials related to the respective unit.

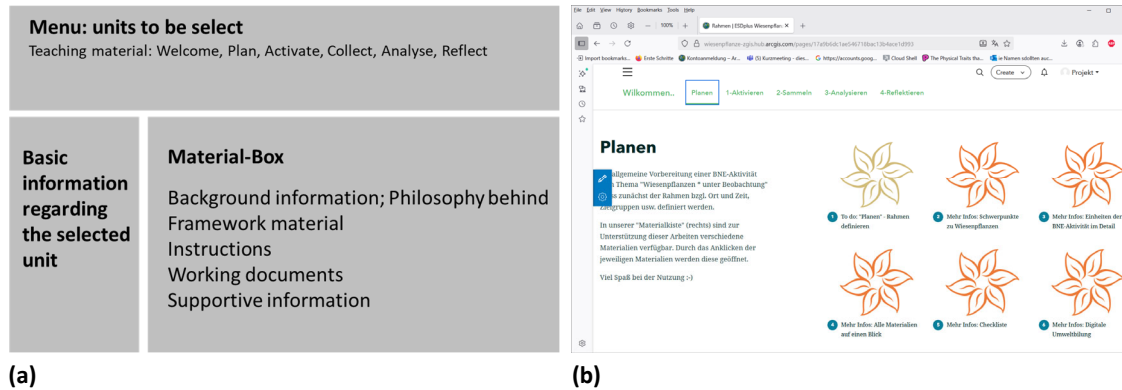


Figure 4.3: Schematic structure of the ESDplus teaching modules (a), and exemplary screenshot (b)

4.1.3 ESDplus training module and materials

Survey participants outline that appropriate and comprehensive training in the use of digital geomedial, especially in the context of ESD, is an important issue (Figure 3.2, Figure 3.3). This requires training resources that are tailored in content and structure to the needs of the ESD-educators.

Content

Similar to the ESDplus teaching modules, the ESDplus training module contains different types of information organized into four categories (Table 4.4): (i) background information, (ii) framework information, (iii) training materials, and (iv) supportive information.

Table 4.4: Types of information required on the ESDplus training module

Content	Detail
Background information	• introduction to the materials, including the philosophy behind
Framework information	• information on the relevance of different training units (training materials) for ESD-educators to use digital geomedial in ESD
Training materials	• materials that refer the different units to learn about digital geomedial use focusing on a certain topic
Supportive information	• additional information which might be interesting in terms of the other information types

By identifying and specifying the competencies relevant for the use of digital geomedial in ESD by ESD-educators, ESDplus first developed a competency catalog that provides a theoretical basis for the development process of training materials. These recognize that geomedial can significantly improve education overall (Bondarenko 2025; Li et al. 2022; Schulze 2020) and that digital geomedial is particularly beneficial for ESD initiatives by promoting learners' environmental awareness (Alazmi 2025). Here, the ESDplus examined the following key approaches to the conceptual integration of geomedial:

- Spatial Thinking (NRC 2006; Plummer et al. 2022; Zwartjes 2012): This approach uses geomedial as a tool to cultivate spatial and analytical reasoning in science education.
- Spatial Citizenship (Gryl 2022; Gryl & Jekel 2012, 2018): This approach emphasizes using geoinformation to enhance communication, encourage civic participation, and foster a global understanding among learners.
- Spatially Enabled Learning (Vogler et al. 2018): Drawing from pedagogical psychology, this approach leverages interactive tools such as web maps and story maps to make learning more effective by providing a spatial context for educational content.

Based on these insights and taking ESD-educators' knowledge of digital geomedial use into account (section 3), the ESDplus training module includes the following aspects (Table 4.5): (i) welcome information, (ii) basic geomedial skills, (iii) spatial data sources, (iv) visualization and implementation, (v) spatial data management, and (vi) advanced topics.

Table 4.5: Aspects addressed by the ESDplus training module

Aspects	Detail
Welcome information	• Philosophy behind the training module and materials • Background, relevance, and overview • Access to the ESDplus training materials • Overview of geomedial skills • Overview of Earth Observation skills
Basic geomedial skills	• Background, relevance, and overview • Knowing digital geomedial use in BNE • Using online maps • Understanding Earth Observation • Learning image interpretation
Spatial data sources	• Spatial data sources: background, relevance, and overview • Using existing spatial data: Open Data and OGD • Using existing spatial data: Earth Observation data • Creating own spatial data: geo tracking • Creating own spatial data: digitize • Creating own spatial data: crowd mapping
Visualization and implementation	• Visualize and implement: Background, relevance, and overview • Create online maps • Create story maps • Visualize Earth Observation data
Spatial data management	• Spatial data management: background, relevance, and overview • Spatial data import and export • Spatial data sharing • Spatial data transformation
Advanced topics	• Advanced aspects: background, relevance, and overview • Advanced digital geomedial use • Advanced Earth Observation

When developing new training activities such as the ESDplus training module and materials, findings and experiences from the field of adult education are central (Detjien 2007; EU 2012; NP BNE 2022; Vogler & Hennig 2013): Thus, it is essential to consider the existing knowledge of the target group and the tools they have used in previous work, as well as their relevance to addressing real-world problems. Accordingly, training measures must always be based on people's current level of knowledge, i.e. existing knowledge must be taken into account or reference must be made to it. As shown in Figure 3.4, there are several tools that are commonly used in everyday life or in non-GI-specific disciplines (Rickles et al. 2017) and that are generally familiar to ESD-educators and that are also used by some of them. Examples include Google Maps, Google Earth, Desktop-GIS, ArcGIS online, and GPS. In contrast, other tools important for education are generally unknown and not used or used less by ESD-educators, such as story maps, Scribble Maps, and EO browsers (Dolenc 2018; Education Group 2025; Tusam et al. 2024). Thus, tools such as Google Maps and Google Earth, which are familiar to most respondents, are particularly well suited for use in basic training measures to convey and explain relevant terms and concepts related to the use of digital geomedial.

The survey findings indicate that the competencies in using digital geomedias in ESD considerably vary among those engaged in ESD. It cannot necessarily be assumed that ESD-educators have the necessary skills to deal with digital geomedias. In addition to providing basic information, the training module offers optional access to further information to specifically address the different prior knowledge and skills of ESD-educators. This includes linking and leveraging various existing content and resources such as videos, best practices, online courses, tutorials, and webinars from e.g. EO4GEO and open ESRI resources that are suitable for the target audience. The ESDplus training module therefore aims to motivate people during the training units to such an extent that they are open to improve their skills through self-directed learning (e.g. regarding the advanced units) and to make them multipliers for the use of digital geomedias in ESD.

Finally, it must be emphasized that ESD-educators have very limited knowledge of EO (Figure 3.5, Figure 3.6), despite the known relevance and suitability of EO data and tools for education and ESD (Asimakopoulou et al. 2023; Dannwolf et al. 2020; Schneibel & Siegmund 2018). Consequently, special attention was paid to EO in the ESDplus training materials (Table 4.5).

Structure

The structure of the ESDplus training module follows the approach of the ESDplus teaching modules and organizes the information into three parts. This is presented in Figure 4.4.

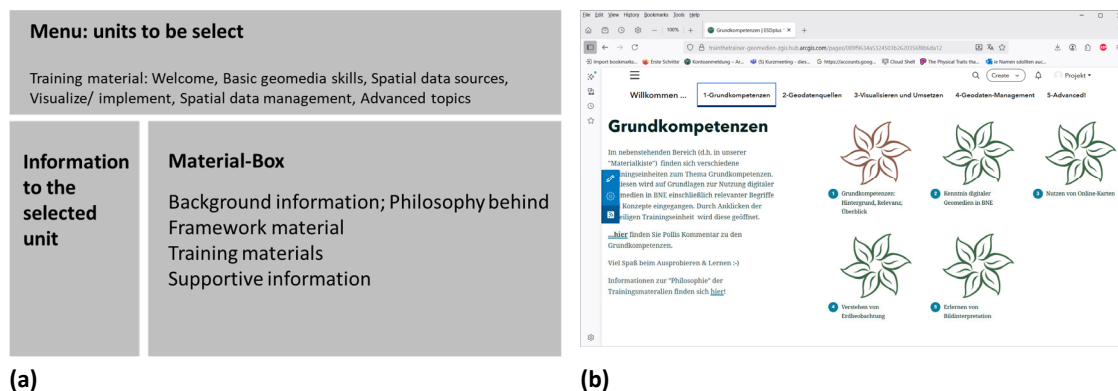


Figure 4.4: Schematic structure of the ESDplus training module (a), and exemplary screenshot (b)

4.1.4 ESDplus glossary

In order to give ESD-educators an additional opportunity to build knowledge and understanding of terms and concepts related to digital geomedias use, which are mostly missing among the target group (Figure 3.6), a glossary has been implemented. In addition to short and easy-to-understand explanations, it also contains links for those interested in further information.

The ESDplus glossary focuses on relevant aspects that are also important in the context of the teaching and training modules and materials as well as the collection of application examples for the use of digital geomedias in ESD. In total, it includes over 70 terms that are also relevant to other aspects of the ESDplus project, such as funding, ESD, and BRs.

4.2 Design and delivery

4.2.1 General aspects

The consideration of guidelines and quality criteria is key to supporting the design and implementation of the user-centered ESD products (NP BNE 2022). This applies to all ESDplus products (Figure 4.1). The findings from the workshops confirmed several aspects of the literature but also provided additional insights (Table 4.6).

Table 4.6: Selected recommendations for material and module design and implementation based on literature and workshop findings (Hamilton 2016; Hennig et al. 2022; Hennig et al. 2024a; Munger 2016; NP BNE 2022; Renz et al. 2014; Wilber 2018; Wrightsell-Hughes 2015)

Criteria	Recommendations
User-Onboarding	No registration, login; open access (i.e., OER)
	Short personal welcome, direct approach to users
	Presentation of the project and product, among other things, through multimedia (short video/audio files); if at all, only short text to read
	Context-related instructions that are optional and available with varying scope and depth (short content with links to further information) to meet the different interests and knowledge levels of ESD-educators
	Highlight context and relevance for ESD, the benefits of using digital geomedia in ESD
Usability, Accessibility, Utility	Conscious and well-considered use of language, i.e. no technical terms from the IT/ GI domain
	Reduced amount of text to read, well-structured, e.g., with bullet points
	Use of multimedia, combination of different multimedia and interactions
	Intuitive, simple and appropriately structured graphical user interface (GUI)
	No unnecessary details, elements, interactions
	Compact presentation of information with opportunities for accessing further information via interactions and links
	Using the same structure and design in all elements that make up the materials and modules, i.e., consistent (i.e., corporate) design of all units and elements
	Attractive design that is appropriate for the target group and domain
	Consideration of F/Z design
Joy of Use	Reduce scrolling
	Using a mascot to lead through the material (honeybee “Polli”)
	Use of a material collection grid design to easily understand the structure
	Simple, compact and short/ concise instructions
	Variation and combination of different multimedia, e.g., images, video, and audio files
	Possibility to access further information (if required/ in the case of interest)
	Context-related instructions that are optional and available with varying scope and depth (short content with links to further information)
	Attractive corporate design (i.e., appropriate for the target group): using colors, fonts, and symbols etc. (including the use of the honeybee “Polli”)

Among the aspects listed in Table 4.6, appropriate structuring and navigation as well as attractive design, including the use of multimedia, are of crucial importance for ESD-educators. Further, ESD-educators highlighted the use of a mascot to guide through the materials. They pointed out that this is an important motivational and engaging factor. This demand is met by implementing the honeybee “Polli”, who not only introduces the materials but also gives explanations in selected situations. Other excitement factors are interaction and opportunity to connect with peers. Finally, all materials are implemented as Open Educational Resources (OER), which is in line with sustainability requirements in teaching (Muuß-Merholz 2020).

4.2.2 Key requirement “targeted integration of digital geomedial use in ESD”

The targeted integration of the use of digital geomedial ESD is crucial. This is underlined by the results of the survey (Figure 3.2) and the workshops. ESD-educators emphasized that the target integration of digital geomedial use into ESD is a fundamental requirement that must always be considered when developing products to support digital geomedial use in ESD. The aspects mentioned by the workshop participants as necessary to achieve this integration are consistent with findings and experiences discussed in the literature (e.g., Detjen 2013; Ehlers et al. 2013; Gryl 2023; Hamilton 2016; Hennig 2020; Hiller et al. 2019; Raschke & Karrasch 2018; Wilber 2018). Selected points, some of which overlap with general design recommendations (Table 4.6), are:

- always present interesting and exciting examples first and highlight their potential for use and transfer to own ESD activities in order to raise ESD-educators’ awareness, interest, and motivation
- link and support all content with engaging examples, including opportunities for adoption in terms of own ESD activities (i.e., to make clear how the use of digital geomedial supports ESD goals and thus enable ESD-educators to recognize the added value and specific potential of digital geomedial to advance ESD goals)
- ensure that all exercises, explanations, and application examples always prioritize ESD
- clearly and explicitly explain how tools can be meaningfully integrated into (own) ESD activities
- go beyond simply presenting digital geomedial and its uses; instead, focus on how digital geomedial use supports ESD
- consider that the use of digital geomedial should never distract from ESD but should support it
- always put practice first and theory last
- illustrate how the combination of analogue and digital materials and methods (e.g., digital geomedial) can complement each other to enable better ESD activities
- provide opportunities to access additional information for (more) interested ESD-educators, such as links to other courses, materials, and tutorials
- consider motivational factors that act as success factors (e.g., design, content, structure, use of mascot)
- do not overwhelm ESD-educators regarding theory, amount of content, complexity
- implement an attractive design in accordance with usability and accessibility criteria as well as user experience

It is essential to stress that ESD-educators need to encounter information that piques their interest and motivates them, especially during the onboarding process. Here, focusing on ESD-related aspects and providing a comprehensive overview is most crucial, as is the opportunity for ESD-educators to access additional information when needed. Furthermore, as already stressed, the content should build on the existing knowledge of ESD-educators and should “pick up” them accordingly. Now, it is important to maintain this motivation and interest among ESD-educators throughout the entire process of using the ESDplus products.

5 Discussion

By fulfilling the objectives pursued with ESDplus (i.e., developing teaching and training materials and modules), further important aspects for promoting digital geomedial use in ESD could be achieved. This includes creating practical and theoretical foundations for the use of digital geomedial in ESD and promoting the development of a corresponding community (Figure 4.1).

5.1 Practical foundations

Educators are key actors in ESD to facilitate learners’ transition to sustainable ways of life. In today’s information society, where information is ubiquitous and its role is evolving (UNESCO 2020b), and

where digitalization significantly impacts our lives (Zancajo et al. 2022), people need skills and competences to handle information and use digital methods and tools. This necessity also applies to ESD. To meet this need, ESDplus has developed and provides appropriate ESD-educators-centered resources. These include not only teaching and training materials and modules, but also a collection of application examples and a glossary (Table 5.1).

These resources support ESD-educators in using digital geomedial media and serve as a practical foundation for (further) improving the integration of digital geomedial media use in ESD. They are characterized by specific aspects regarding content, structure, design, and delivery mode (section 4). These products are designed to meet the needs of ESD-educators and ensure usability, usefulness, and relevance for this target audience. In addition to the ESDplus website, the ESDplus products are also available on other platforms and portals, including iDEAS:lab, Sustainicum, AGEO, and the “BNE-Konferenz in der EUREGIO” and are promoted through a wide range of activities (see Appendix, Table 3, 4, and 5).

In addition to providing information to ESD-educators, especially the collection of application examples serves several other purposes. Like other laypeople who use digital tools, ESD-educators must also recognize the suitability and potential of digital geomedial media use in ESD. Raising awareness, stimulating interest and motivation, building acceptance and reducing skepticism are essential foundations for ESD-educators to be open to the use of digital geomedial media in ESD. The importance of these aspects is underpinned by findings regarding (online) participation. For example, various researchers emphasize that users' interests and motivations are key success factors for using digital tools in participatory activities (Haltofová 2020; Hennig 2020). Thus, personal resources, such as interest and motivation, are prerequisites for using digital tools, which must also be centered on users' requirements regarding content, usability, and accessibility (Figure 5.1; van Dijk 2012). In conclusion, even with user-centered products such as those developed in ESDplus, ESD-educators must first have the according personal resources as a basis for all subsequent activities.

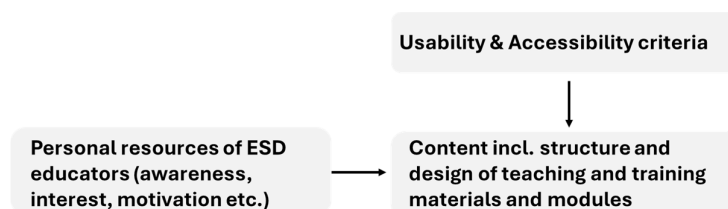


Figure 5.1: Success criteria to support and foster digital geomedial media use in ESD (adapted from Haltofová 2020; Hennig 2020; van Dijk 2012)

5.2 Theoretical foundations

In the context of the development of the ESDplus products, ESDplus provided different theoretical foundations that are also valuable for others. This includes: (i) a competency catalog, (ii) a specially created workflow (i.e., the ESDplus workflow), and (iii) product requirements and recommendations for meeting the specified requirements.

Competency catalog

As a fundamental step for the design and implementation of the ESDplus materials and modules, we have developed a competency catalog that describes the necessary knowledge and skills for ESD-educators to effectively use digital geomedial media in ESD while also considering the skills that can be built in learners (section 3.1.3). The competency catalog is available as part of the ESDplus teaching module (<https://zgis.maps.arcgis.com/sharing/rest/content/items/c64123c956d84ee694c7d7881bbfcb12/data>). However, it not only serves as a framework for the design and structuring of the ESDplus materials

and modules but can also support the development of other comparable training resources. Further, it can be considered as a starting point for creating an appropriately oriented curriculum regarding digital geomeia use in ESD.

ESDplus workflow

As a basis for the design and implementation of materials and modules that support the use of digital geomeia in ESD, ESDplus provided requirements and recommendations for fulfilling the specified requirements. In order to have this information at hand and to truly consider it in the design and implementation of the ESDplus products, a specially developed workflow – based on the selection and combination of design approaches, process models and methods (Figure 2.1) – was crucial.

This workflow facilitated different types and levels of participation on part of ESD-educators and brought numerous benefits. Thus, user needs were not only identified and understood but also effectively implemented. This ensures that ESDplus products truly meet ESD-educators' needs. This is discussed in greater detail in Hennig (2024a) and Hennig et al. (2024a) and can be used as inspiration for others in the development of comparable products.

Despite these advantages, it is important to note that involving laypeople, such as ESD-educators, in the development of such resources can be challenging and cumbersome. Successful participation requires commitment, time and appropriate financial and human resources (Hennig et al. 2022; UNECE 2008). As shown in ESDplus, this also relates to several issues that are consistent with experiences from other initiatives (e.g., Hennig & Vogler 2016): (re)motivating participants, addressing and managing discussions on unexpected problems, and dealing with different knowledge, skills, motivations, and backgrounds.

Product requirements and recommendations

ESDplus offers valuable insights into the requirements of ESD-educators for the development of teaching and training modules and materials that support the use of digital geomeia in ESD, including recommendations. These requirements and recommendations emphasize user-centered content, structure, design, and delivery modes and are based, among other things, on existing literature. Examples are

- appropriate use of colors, symbols, and language (usability and accessibility: UNECE 2008; usability.gov 2017)
- creating an attractive, but not overwhelming, first contact with the materials (user onboarding: Munger 2016; Renz et al. 2014)
- addressing people's motivation (participation: Haltofová 2020; Hennig et al. 2022)
- taking existing knowledge into account and emphasizing practical work (adult education: EU 2012; Vogler & Hennig 2013).

Additional recommendations include reusing existing suitable and proven materials and using multimedia (e-learning: FAO 2021; Hamilton 2016), as well as compliance with guidelines on ESD materials (NP BNE 2022). Further, specific recommendations have been developed to facilitate the targeted integration of digital geomeia in ESD. This is a key aspect emphasized by ESD-educators and on which no information was previously available.

5.3 Community building

In the context of ESDplus, engaging with the target group, i.e., ESD-educators, was crucial. This involvement encompassed different aspects. First, it referred to the participation of ESD-educators in the development process of the ESDplus products. Second, it included public relations and

dissemination activities aimed at informing the public, target group, and scientists about the project, its results and the ESDplus products. These activities included in-person events such as workshops, science-to-public events, and conferences, as well as articles in local media and scientific journals, contributions on various platforms and newsletters. Third, several teaching and training activities were conducted. Further information on these activities can be found on the ESDplus website (<https://esdplus-zgis.hub.arcgis.com/pages/9c49713944ac49b2b27dda329d6fcd28>) and in the Appendix (Table 3-5).

These activities contributed to building a community of ESD-educators interested in digital geomedial use in ESD, which brings several benefits. Communities facilitate communication and engagement with stakeholders and multipliers (Fritz et al. 2017) and they address ESD-educators' information needs, raise their awareness, interest, and motivation (ER 2014; Sierra-Piedrahita 2018). Additionally, they provide ESD-educators with the opportunity to share their experiences of using digital geomedial in ESD, including its benefits and relevance. This allows learning from each other (Hennig 2020; van Dijk 2012) and corresponds to the concept of peer-to-peer learning, which highlights the benefits of collaborative learning among participants with the same level of knowledge (Fritz et al. 2017; Keerthirathne 2020; van Dijk 2012). This also offers the opportunity to engage ESD-educators who have little interest and a rather negative attitude towards using digital geomedial in ESD. It helps reduce rejection and increase interest in digital geomedial use in ESD. Further, communities facilitate seeking help from others (Hargittal 2002; van Dijk 2012). Particularly personal connections and the resulting relationships can foster a sense of common ground and trust regarding the use of digital geomedial in ESD (compare Blanchard et al. 2022; McCully et al. 2011). To conclude, it is well-known that the existence of a community and the opportunities communities provide motivate individuals to use online materials, such as the ESDplus products (Hennig 2020).

In this context, the mini-conference "BNE-Konferenz in der EUREGIO" (funded by the INTERREG program BY & AT 2021-2027; <https://bne-konferenz-euregio-zgis.hub.arcgis.com/>) deserves special attention. Organized by the Department of Geoinformatics PLUS and GI_PLUS, this event was held in context with the ESDplus kickoff meeting. Its primary focus was on strengthening and expanding the community of ESD-educators focusing on digital geomedial use in ESD (here by using several of the developed Esopus materials). It is important that this community continues to exist even after the end of the project. Exchange and connections among ESD-educators will ensure that the various ESDplus products are shared, used, and further developed, thereby guaranteeing the sustainability of the ESDplus results.

6 Conclusion, Outlook

Regarding societal changes such as digitalization, ESD requires new methods and approaches. To address this, the ESDplus project aimed to enhance ESD by exploring and strengthening the connection between digital geomedial use and ESD, focusing on the development of ESD-educator-centered products that support this. But what should such materials look like? To answer this question, a workflow was developed in ESDplus that takes into account the need to comprehensively understand the needs of ESD-educators and then consider those needs when implementing truly ESD-educator-centered products. These materials, developed in collaboration with ESD-educators, include teaching and training resources, a collection of application examples regarding the use of digital geomedial in ESD, and a glossary explaining selected key terms important for ESD-educators. Among the specified requirements, overarching aspects were to ensure the targeted integration of digital geomedial use into ESD and to raise awareness, interest and motivation among ESD-educators. Considering these issues during the development of the ESDplus products was crucial to getting ESD-educators to be open to the use of digital geomedial in ESD. Thus, ESDplus products can contribute to the promotion and

development of ESD, which is particularly relevant for BRs due to their important role in both sustainable development and ESD.

By designing and implementing the ESDplus products, we established a practical foundation (consisting of teaching and training materials and modules, a collection of application examples, and a glossary) as well as a theoretical foundation (comprising a competency catalog, a specific workflow, and requirements and recommendations for the generation of ESD resources). Additionally, ESDplus supported the development of a respective community. These aspects make it possible to leverage the potential of digital geomedial in ESD while addressing barriers to its use, ensuring its application in ESD in BRs and beyond, even after the project. In summary, the ESDplus products, along with the experiences gained during the project, facilitate the further development of ESD methods. However, before focusing on activities like training, it is crucial to raise awareness and build interest and motivation among ESD-educators. Much remains to be done in this regard, particularly in terms of information and communication, as well as promoting and maintaining community building. Nevertheless, striving for improved ESD makes these efforts worthwhile.

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8 Appendix

Table 1: Structure and content of the ESDplus online questionnaire

Question (number and short description)		Description
1	Organization name	Open – short free text
2	Valuation of the use of digital geomedia	Closed – array
3	Level of use of digital geomedia (1: none – 5: high)	Closed – array
4	Examples of the potential use of digital geomedia in analogue ESD	Open – multiple short texts
5	Familiarity with terms and concepts	Closed – array
6	Opportunities for support	Closed – multiple choice
7	Activities carried out related to digital geomedia	Closed – array
8	Topic areas for use in ESD	Closed – multiple choice
9	Opinion on the use of digital geomedia	Open – multiple short texts
10	Barriers to the use of digital geomedia in ESD	Closed – array
11	Best-practice examples	Open – multiple short texts
12	Sources of information regarding ESD	Open – multiple short texts
13	Added value of using digital geomedia in ESD	Open – long free text
14	Email address to send results	Open – short free text

Table 2: ESDplus Workshops and Test events

Workshop/ Event	Date (planned)	Date carried out	Number of participants
Geo Citizen Science 1 WS.	08/2023	11. Oktober 23	10
Earth Observation 1. WS	09/2023	20. Oktober 23	11
Train the Trainer 1. WS	10/2023	4. Dezember 23	14
Geo Citizen Science 2 WS.	01/2024	7. März 24	11
Earth Observation 2 WS	02/2024	21. März 24	14
Train the Trainer 1. WS	03/2024	11. April 24	12
Test event GCS	10/2024	13. August 24	12
Test event EO	11/2024	17. Oktober 24	18

Table 3: Selected activities and measures for knowledge integration

Methods, Approaches	Implemented
Multiplication effects on part of the Biosphere Reserves	• Transfer to Berchtesgaden National Park • BR partner-school teachers participated in workshops • Presentation of ESDplus results at the MMV conference (Management and Monitoring of visitors) in the context of two Sessions hosted by the ESDplus team
Openly accessible products	• ESDplus website: https://esdplus-zgis.hub.arcgis.com/ • iDEAS:lab website: https://ideaslab.plus.ac.at/pages/6ea8804eddaa40efb7acfd911562b2f5 • Sustainicum website: http://www.sustainicum.at/resources/units • AGEO website: https://www.ageo.at/ageobox • BNE-Konferenz in der EUREGIO website • GWB Schule: https://gwb.schule.at/course/view.php?id=2069
Transfer and use in learning laboratories	• Training workshop integration in iDEAS:lab offers • Communication using publications, posters and conference sessions • mini-conference “BNE-Konferenz in der EUREGIO” addressing ESD-educators, held in cooperation with iDEAS:lab
Teacher initial and in-service training as well as non-formal education	• Publication of selected materials in GWU (a journal addressing teachers) • Participation of (future) teachers in the ESDplus workshops • Presentation and discussion of the ESDplus approach and materials in the framework of university courses (initial teacher training) • Presentation and discussion in teacher Training (Bundes-AG GW, Webinar Reihe GW & Geomedien) • Final project end event in connection with the BNE-Konferenz • Hosting of education sessions at the AGIT 2025 conference • In addition: presentation of the ESDplus approach and materials in the context of other courses – to communicate the relevance of non-formal ESD as it is done in protected areas this included Workshops in the BNE for HEI course, DITACT, Informatica Feminale, CEEPUS teaching activities • Master thesis ESD-educator-centered continued education measures (in progress)
Cooperation and partnership with schools	• Use of ESDplus material (e.g. geotagging) in the context u3Green events (https://u3green-zgis.hub.arcgis.com/) • Internships for high school students (3)

Table 4: Selected dissemination activities and measures

Category	Used channels
Scientists	• 8 publications (plus one still under review) • 10 conference presentations • 4 sessions at 2 conferences (MMV 2024; AGIT 2025) • Timeline and results presentation on the ESDplus project website (https://esdplus-zgis.hub.arcgis.com/pages/e14a6263ae5240d1a75f339937b4a1b6) • Several posts on LinkedIn, Z_GIS social media channels, and partners' online resources • EU Service-Learning Contest (CIVIS OL) • 4 Poster presentations
ESD trainers (Practitioners)	• multiplier events (workshops, symposia by stakeholders) • further education and lifelong learning initiatives • cooperation/ exchange with other ESD organizations/ initiatives • project website, partner websites • exchange with Berchtesgaden National Park on use/ combination of digital geomedia • mini-conference "BNE-Konferenz in der EUREGIO"
ESD managers (Practitioners)	
ESD-educators (Practitioners)	
Learners, i.e. the public	• Open Day events, i.e., science-to-public events (e.g., PLUS open day) • BR dissemination events/ activities: publication on website and newsletter • Project CMS website, Z_GIS social media channels • Podcast (included in ESDplus materials discussing potential of digital geomedia use; included in teaching materials) • ESDplus flyer and brochure, ESDplus roll-up, ESDplus postcard and bookmark • Testing with UNI 55-PLUS students • FFG internships for high school students

Table 5: Selected Linkages to international research programs/ networks/ cooperations to promote ESDplus results and products

Initiatives	linkage
CIVIS	OL and BIP activities
CEEPUS	Teaching mobilities: activities focusing on ESDplus approach and materials
ACA*GIS	GISCA conference and workshops
Allianz Nachhaltiger Universitäten Österreichs	Workshops using, e.g., ESDplus products
AGEO	Sharing of ESDplus products
Sustainicum	Sharing of ESDplus products
EUREGIO	Sharing of ESDplus material in context of the "BNE-Konferenz in der EUREGIO"; inspiring this mini-conference