Digital Geomedia and their Use in Education for Sustainable Development: Status Quo and Opportunities for Improvement

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Abstract

Education for sustainable development (ESD) requires new and updated approaches, including the use of information and communication technologies like digital geomedia. However, despite their numerous possibilities, digital geomedia appear to be under-utilized in ESD, meaning that their full potential remains unused. This leads to unresolved questions: How are digital geomedia currently used in ESD, and what form do they take? What are the obstacles and possibilities for integrating digital geomedia in ESD? How can we address them? To answer these questions, the ESDplus project conducted an online questionnaire among organizations that carry out ESD (protected areas, museums, nature conservation associations and zoological gardens). The results show that one-third of the respondents have never used digital geomedia, and only 4% apply digital geomedia in their ESD activities. Even though almost two-thirds see great potential in the use of digital geomedia, a majority still prefer to use traditional analogue methods in ESD. The following issues are key to improving the use of digital geomedia: providing an overview of digital geomedia; their integration in ESD activities, and the provision of suitable training materials.

Keywords:

learning with geoinformation, informal education, environmental education, geodata and geoinformation

1 Background and research context

The aim of Education for Sustainable Development (ESD) is to raise people's awareness of sustainable development, and to motivate and empower them to adapt their behaviour accordingly. ESD, which often takes place in addition to formal education, is intended to offer learners a holistic perspective by integrating economic and socio-cultural aspects. It is based on the acquisition of new knowledge, skills and competencies, as well as values that are essential for shaping a sustainable future (Ermakov et al., 2019; UNESCO, 2017, 2018). It uses the Head-Heart-Hands technique (Head: cognitive/logical; Heart: emotional; Hands: practical;

UNESCO, 2019) and incorporates elements of concepts such as problem-based, project-based and active learning (ALPARC, n.d.; ESDplus Team, 2024; Zorenböhmer et al., 2022).

ESD not only makes use of various teaching and learning methods and approaches (e.g., participatory learning, experiential learning and transformative learning), but also strives to make use of and develop innovative methodology. New tools and an appropriate learning environment are required to integrate views on ecological, economic and social aspects of sustainable development (Kruse-Graumann, 2007). This requires far-reaching changes in the way ESD is practised (O'Grady 2023; UNESCO 2013, 2017).

Due to advances in information and communication technologies (ICT) and in view of the current societal transformation – in particular towards a greener society and the digital transition – innovative toolkits have become available for ESD as well. The use of unconventional classroom settings along with new digital media were stimulated through the lockdowns of the Covid-19 pandemic and now facilitate new possibilities of, for example, blended learning and self-paced training (Fauville et al., 2013; Hennig, 2006; Lude et al., 2013; Referowska-Chodak, 2020).

The new possibilities also include the use of digital geomedia (de Miguel Gonzalez, 2012; Hennig et al., 2013; Jekel and Gryl, 2020). Examples are location-based games (e.g., Geocaching), web-mapping tools (e.g., Scribble Maps), virtual globes (e.g., Google Earth), and data-capturing apps (e.g., GPS-Essentials). Digital geomedia also include data visualization tools such as interactive web maps, story maps and interactive dashboards, as well as tools to access spatial data such as satellite imagery, open government data and volunteered geographic information.

This variety of ways to analyse, display and visualize geodata can be used to support, enrich and amplify educational goals. Digital geomedia are a product of the shift in cartography from static paper-based or scanned maps to interactive and user-centric digital maps (Traun et al., 2013). Such web-based information services empower users to explore spatially contextualized contents in a user-driven and managed manner – ideally across scales. Technically, this involves the integration of (heterogeneous) geodata, seamless web-based representation, and advanced visualization techniques. Open geodata and open-source platforms provide the foundation for information exchange amongst individuals and communities (Diamond, 2015; Gryl & Jekel, 2012; Thielmann et al., 2012).

The use of digital geomedia has promoted new vitality in teaching and education generally, as well as in ESD in particular. As stressed by Vogler et al. (2018) in the context of Spatially Enabled Learning, embedding digital geomedia in an educational context has improved teaching effectiveness and introduced a new dynamic of learning by delivering spatial context and representations.

Experiences and opportunities deriving from the use of digital geomedia relate to "learning by doing" and the provision of an interface between physical and digital space. Moreover, working with spatial data using different methods and tools can provide new and interesting insights into the topic under consideration (including ESD topics), not only through spatialization and visualization but also through the learner's own active engagement (BMBWF, n.d.; Vogler et

al., 2018). Additionally, digital geomedia provide excitement and motivation factors (Passey et al., 2004; Vogler et al., 2018).

Using digital geomedia in ESD can have numerous benefits (Anunti et al., 2023; Buck et al., 2022; de Lázaro-Torres et al., 2023; Giardino et al., 2014; Mohammadzadeh, 2019; Pokojski et al., 2018), for example enhancing awareness of environmental and ecological issues; promoting critical thinking and facilitating transformative action among learners; fostering sustainability practices and community engagement; increasing location awareness in various ESD initiatives.

In a pedagogical context, spatially enabled learning (Vogler et al., 2018) and Spatial Citizenship (Gryl & Jekel, 2012) both comprise measures to boost the efficiency of teaching and formal education through (digital) geomedia. Applying a spatial thinking approach, Zwartjes (2012) uses geomedia to add a powerful perspective to understanding complex matters in science subjects, and enhances spatial and analytical thinking in general. Geomedia allow non-conventional visual communication and promote co-creation (whether in actual design activities or social construction) in public participation and citizen science (Gryl & Jekel, 2018).

But solutions to the "old" issues of sustainable development must go beyond promoting simple behavioural changes, such as "turning off the light". Rather, ESD today is linked with citizenship actions because the community itself is an important place of transformation. ESD and citizenship education thus overlap (Lockhart, 2016; UNESCO, 2018).

Nevertheless, digital geomedia is currently underexploited in ESD, despite the key role that geomedia play in the complex societal challenges we face, including sustainable development, which raises the following questions. What does the use of digital geomedia in ESD look like? What best-practice examples exist? What barriers and hurdles need to be overcome to fully exploit the potential of digital geomedia in ESD? What specific requirements do we encounter amongst ESD educators? How can these be addressed?

These aspects are studied as part of the ESDplus project (https://esdplus-zgis.hub.arcgis.com/). To further support the use of digital geomedia in ESD, suitable teaching and training materials have been designed by ESDplus, whose overarching aim is to promote and strengthen the use of digital geomedia in ESD, in informal settings, for all members of society. Two (prototypical) modules aim to motivate environmental educators to use digital geomedia in ESD. These online teaching modules are supplemented by training resources (an online train-the-trainer module). Intensive cooperation with partners (the Austrian Biosphere Park Lungau and the German Biosphere Region Berchtesgadener Land) is key to the project.

2 Methods

A survey was carried out among organizations in Germany, Austria and Switzerland to gain insights into their use of digital geomedia in informal ESD. Organizations included protected areas, environmental education institutions, nature conservation associations and authorities, zoological gardens, alpine associations, etc., all of which focus on environmental issues and thus ESD. We sent an online questionnaire to around 1,400 organizations (October 2023 – January 2024), with a request to share the questionnaire with others.

The questionnaire was created according to the principles of empirical social science research. Accordingly, particular attention was paid to question types, questionnaire structure and layout, and pre-testing was carried out (Callegaro et al., 2015). The questionnaire was implemented using the online survey tool LimeSurvey (https://www.limesurvey.org).

The results of literature and internet research, as well as a preparatory workshop with representatives of the Biosphere Park Lungau and the Biosphere Region Berchtesgadener Land, served as the basis for the development of the questionnaire. The definition of digital geomedia was kept quite open in order not to influence those surveyed and to exclude initiatives, such as citizen (geo)science, which are not themselves kinds of digital geomedia but make use of digital geomedia.

Based on feedback from internal pre-testers (i.e. members of the project team and partners) and external ones (i.e. selected organizations and individuals carrying out ESD), the questionnaire was evaluated and improved. Comprising 14 questions (Table 1), the online questionnaire (https://umfrage.sbg.ac.at/index.php/318347) focuses on: (i) general evaluation of extent of the organization's use of digital geomedia; (ii) use of tools, knowledge of terms and concepts, activities carried out in connection with the use of digital geomedia and geodata; (iii) barriers and support possibilities when employing digital geomedia in ESD; (iv) opinion on the suitability and/or relevance of digital geomedia in ESD; (v) experience and/or knowledge of suitable topics for using digital geomedia in ESD, analogue ESD activities that could be carried out using digital geomedia, best practice examples, and platforms used by ESD practitioners for information about ESD methods and tools; (vi) advantages perceived in connection with the use of digital geomedia in ESD.

Table 1: Structure and content of the ESDplus online questionnaire

Question		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

The responses received were viewed and (pre-)processed. This included identifying valid questionnaires (i.e., which answered at least one question). The valid questionnaires were statistically analysed using R in the integrated development environment RStudio. The open questions (Table 1) were evaluated using Mayring's inductive category formation of qualitative content analysis (Mayring 2019, 2021, 2022).

3 Results

Although 239 people opened the questionnaire, only 83 submitted valid responses. The results show that one-third of those surveyed had never used digital geomedia in ESD; only 4% used digital geomedia in ESD extensively (Figure 1); 69 respondents stated that they preferred to use traditional (i.e. analogue) geomedia in ESD, and 22 saw digital geomedia as only partially suitable for ESD activities and initiatives (Figure 2). However, 63% of respondents saw great potential in the use of digital geomedia in ESD; 40% of them outlined that it requires extensive training for ESD practitioners.

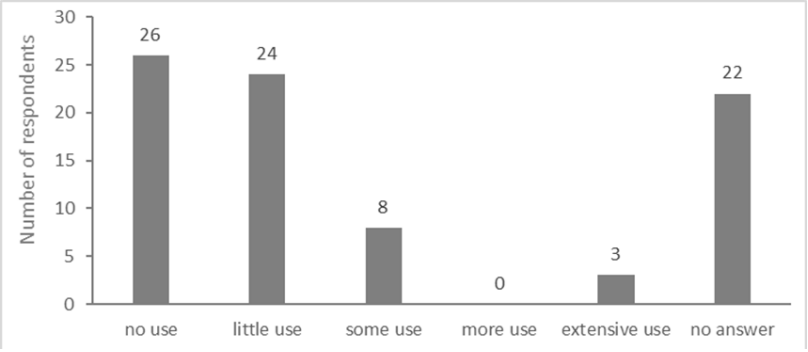


Figure 1: Extent of use of digital geomedia in organizations active in ESD (N=83)

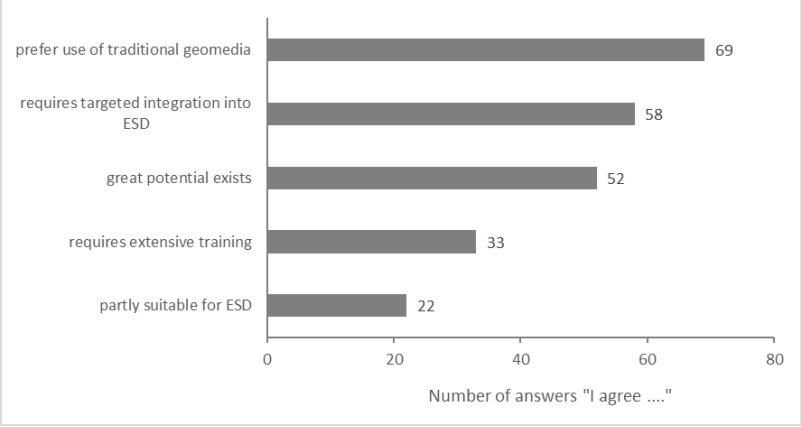
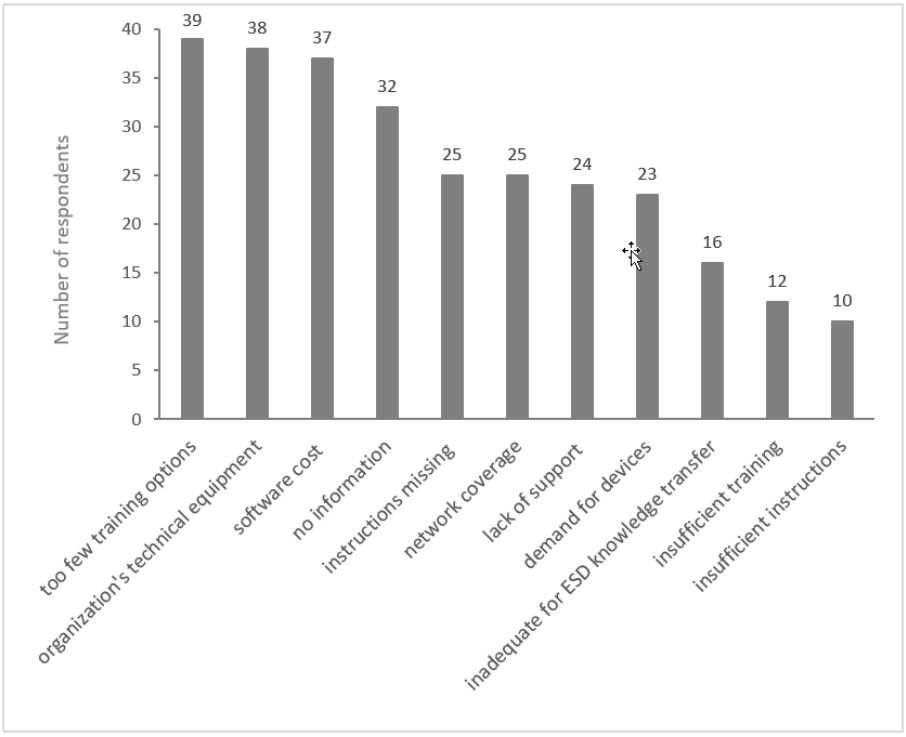


Figure 2: Agreement with selected aspects of using digital geomedia in ESD (N=83)

(a)



(b)

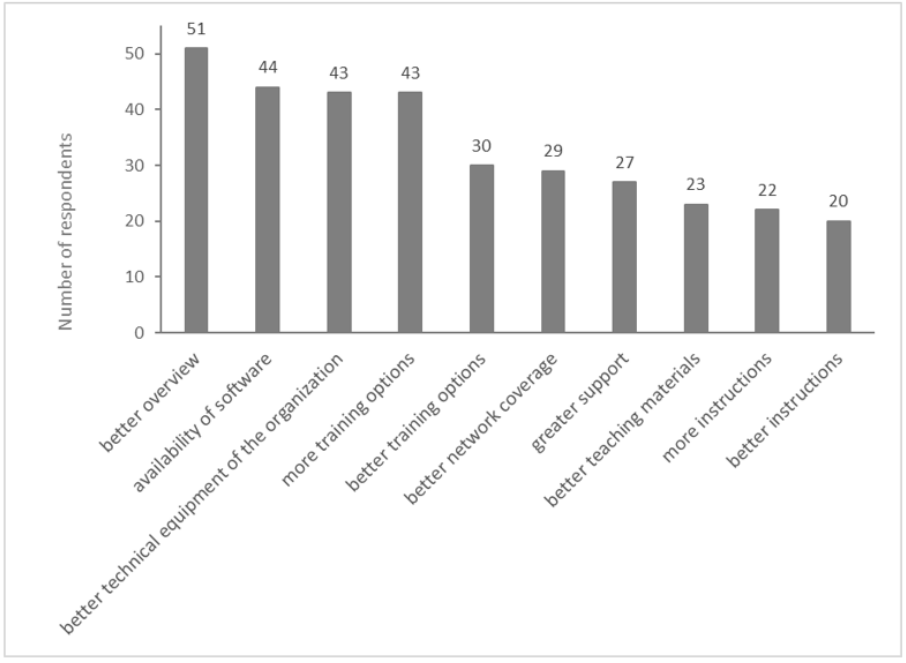


Figure 3: (a) obstacles and **(b)** possibilities to support the use of digital geomedia in ESD

Respondents had the opportunity to add further information to their responses regarding obstacles to, and support in, the use of digital geomedia in ESD. In addition to the statement that analogue methods are generally more suitable, they identified a number of barriers. These included the need for appropriately competent staff, the time factor for preparation, a lack of overview and understanding of the use of digital geomedia in ESD, financial issues, the lack of pedagogical concepts or understanding of the pedagogical connections to the use of digital geomedia in ESD, the lack of relevance for the target group, the need for training, the thematic unsuitability of digital geomedia for the established ESD programmes, the time-consuming implementation, and general resistance to using digital geomedia.

As types of further support required, respondents mentioned the availability of specially trained staff, the provision of background information, a suitable time frame for the integration of geomedia into ESD, appropriate financial resources, integration into existing digital offerings, presentation of practical examples, ensuring appropriateness of the solutions proposed, and use of serious games.

Among digital geomedia, Google Maps and Google Earth are known and used by most respondents (Figure 4). However, the respondents stated that they know and use Google Earth but not digital globes, even though Google Earth is itself a digital globe. This should be taken into account when interpreting the survey results, as it indicates a lack of understanding, on the part of the respondents, of the underlying concepts and terms.

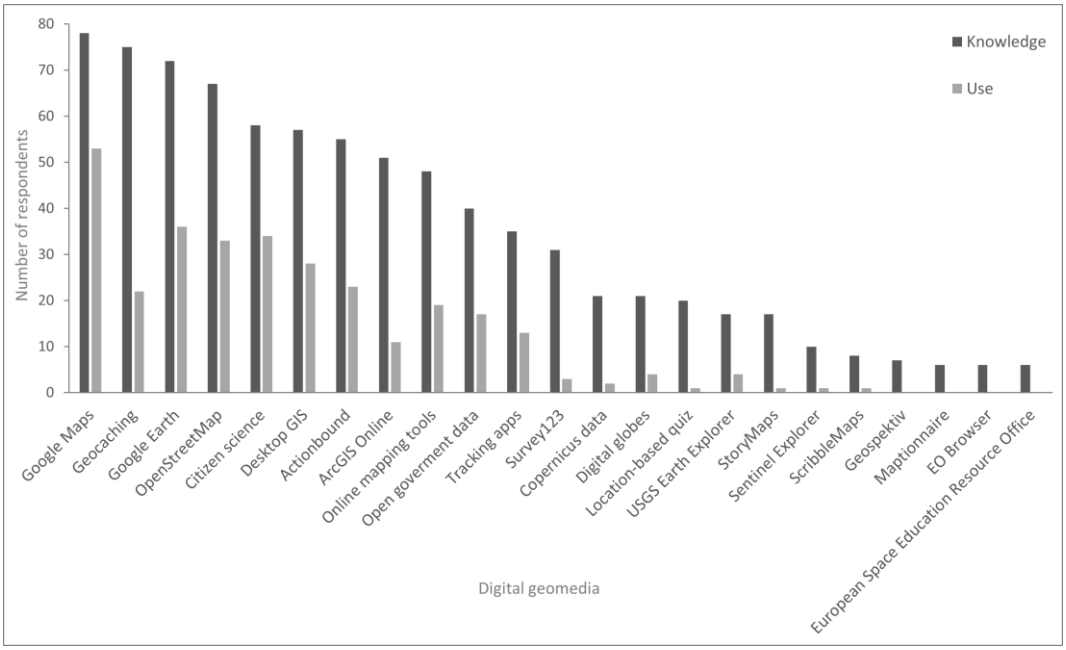


Figure 4: Respondents' knowledge and use of digital geomedia

Best-practice examples were listed by 28 people. The examples given included location-based games (Geocaching, Actionbound), online maps (Google Maps), virtual globes (Google Earth), geoportals (OGD), GPS-related tools and apps, and Citizen Science initiatives. Advantages of using digital geomedia in ESD were described by 59% of those surveyed, encompassing aspects such as the use of current data, easy ways to combine different types of information with each other, addressing young people, a contemporary and interactive approach, and relation to everyday life (e.g., using smartphones).

4 Suggestions for increased use of digital geomedia in ESDResults

The questionnaire results highlight a number of interrelated aspects that are important for encouraging people to actually leverage digital geomedia in ESD, in particular the provision of appropriate digital geomedia tools and an overview of digital geomedia, demonstrating opportunities for a targeted integration of digital geomedia into ESD, and enhancing the availability of tailored training materials and opportunities. These aspects can be addressed through the means presented in Figure 5.

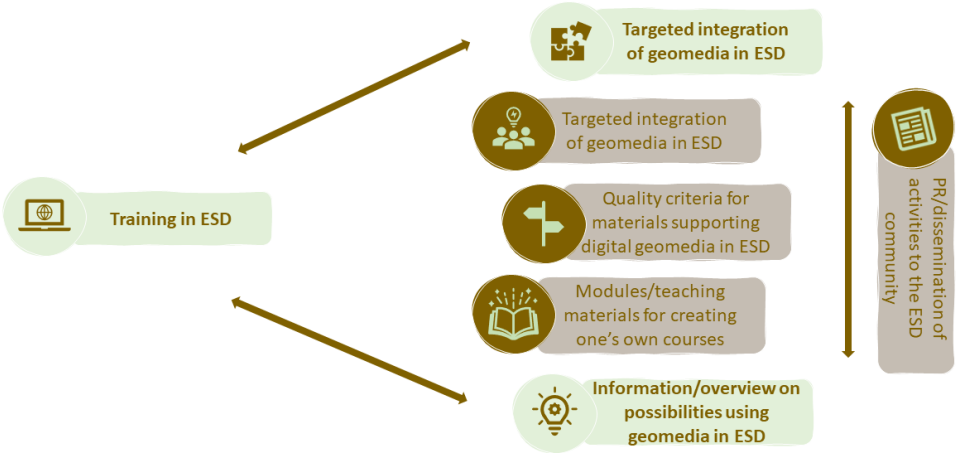


Figure 5: Aspects of the use of digital geomedia in ESD and measures for improving it

4.1 Information and overview regarding digital geomedia and their use in ESD

Although respondents recognize the significant potential of digital geomedia for ESD, they are also critical of their suitability. The majority of ESD practitioners still prefer the use of analogue or traditional methods and procedures (Figure 2). With regard to digital media, the 'Final Report on Targeted Environmental Education and Education for Sustainable Development of the German Umweltbundesamt' (UBA, 2020) implies that the application of digital geomedia within ESD is quite popular, referring to the download of materials and multimedia content in apps, audio walks, or short videos that may be integrated into educational measures. (The report does not use the term 'digital geomedia' itself.)

Reasons for the scepticism of ESD educators include a lack of information about, or an overview of, the possible uses of digital geomedia in ESD (Figure 2, Figures 3a and 3b). To counteract this, public relations activities and dissemination through various events (e.g., conferences), networks, platforms and journals, and blogs (e.g., Umweltbildung.de, Umweltbildung.at) can play a key role. Both online and offline communication (especially face-to-face contacts) and their combination need to be considered to bring the use of digital geomedia closer to those engaged in ESD (McCully et al., 2011).

Furthermore, building a corresponding community is of central importance. On the one hand, this enables communication, engagement, and collaboration with stakeholders and multipliers (Fritz et al., 2017; Hennig et al., 2022). On the other hand, it opens up the possibility for peers who have experience in the use of digital geomedia in ESD to share their experiences and perspectives regarding benefits, interests, relevance, importance, possible uses, etc. with others. This is in line with the concept of peer learning, which underlines the benefits of involving participants of the same level in collaborative learning (Keerthirathne, 2020).

Finally, while relevant information on digital geomedia and its use is available for formal education (e.g., in secondary school education; Schmid, 2018), there is no comparable information for ESD. The available literature focuses mainly on aspects such as location-based games (Baier & Gottein, 2016) and digital rallies (Hiller et al., 2019), although there is some discussion of other possibilities, for example digital story mapping (Anunti et al., 2023), online mapping (Hennig et al., 2022), and using remote sensing data and tools (Jahn et al., 2011).

Accordingly, there is a need for materials that clearly show the possible uses and potential of different types of digital geomedia in ESD, including links to the relevant literature. Also helpful would be reports of direct experience and examples of actual applications. This lack of concrete information is stressed by the questionnaire's respondents (Figure 3a and b). A step in this direction is the ESDplus portal, which gives access to just such actual examples, the related literature, and information about the advantages of using digital geomedia (https://esdplus-zgis.hub.arcgis.com/pages/best-practice-beispiele).

In addition, best practice examples on the part of people engaged in ESD need to be collected. Sharing information with others, including information on best practice, supports community building while promoting the use of digital geomedia in ESD. In addition, such sharing meets sustainability requirements in teaching (Muuß-Merholz, 2020).

4.2 Targeted integration into ESD

Hiller et al. (2019) distinguish between different types of learning in the context of digital geomedia (Figure 6), but regardless of the type of learning, integration of digital geomedia into ESD is not sufficient in itself: it must also be clearly highlighted. This is a crucial point for ESD educators (Figure 2). The use of digital geomedia must be aimed at achieving ESD goals (Section 1) and not take place just for its own sake (Hiller et al., 2019). In other words, it must be targeted. It is important to emphasize that digital geomedia open up many possibilities, such as enriching ESD by providing new forms of making and sharing meaning. This may contribute to changing people's perceptions of, and attitudes to, the environment, thus providing great potential for learning (Gryl, 2023).

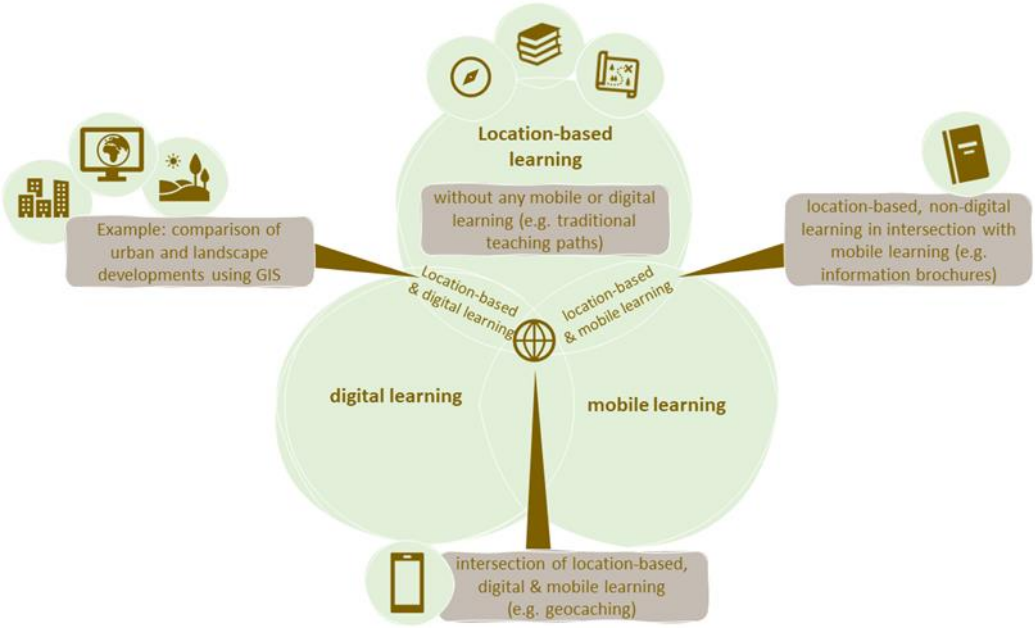


Figure 6: Types of learning in the context of digital geomedia (based on Hiller et al., 2019)

The possible uses of digital geomedia must be described in such a way that people who are involved in ESD see their inherent potential – notably in comparison to analogue methods and procedures (Raschke & Karrasch, 2018). It is also important to demonstrate the value of combining analogue and (geo)digital methods (McCully et al., 2011) and how they complement each other (Ehlers et al., 2013).

4.3 Training

For respondents, appropriate training on how to use digital geomedia (especially in the context of ESD) is an important issue (Figure 2, Figure 3a). The need for specialist trainers is highlighted as pivotal to support the use of digital geomedia in ESD (Section 3). This can be addressed, on the one hand, by creating new materials for training the trainers which address the requirements and needs of ESD practitioners, and, on the other hand, by sharing information and materials, such as tutorials and webinars, that are explicitly developed for lay people using geoinformation and geomedia. These materials are relevant also for teachers in the formal education sector.

In addition, increasing the offer and creating new courses and events on the use of digital geomedia in ESD are recommended. Such target group-centred training measures are already carried out by organizations such as the Bavarian Academy for Nature Conservation and Landscape Management (e.g., on the use of new media for educational trails).

When developing training activities and materials to prepare ESD practitioners for the use of digital geomedia in ESD, findings and experiences from the field of adult education more

broadly are central. These include: (i) paying attention to the existing (level of) knowledge of ESD trainers; (ii) referring to tools already used in work and/or everyday life; (iii) focusing on the interests and areas of special knowledge of ESD trainers; (iv) emphasizing practical work (Detjen, 2007; European Union, 2012; NP BNE, 2022; Vogler & Hennig, 2013).

In our case, since the majority of the respondents are familiar with Google Maps and Google Earth, both tools are particularly suitable for use in training activities. Working with these specific tools, relevant terms and concepts related to the use of digital geomedia more broadly can be explained, without people being distracted by technical barriers. By incorporating people's interests and previous experience, theoretical aspects can be conveyed without overwhelming ESD trainers or their trainees, thus helping to maintain everyone's motivation.

The survey findings flag up that the existing competencies in the use of digital geomedia in ESD vary considerably among ESD practitioners. We cannot assume that ESD educators have the relevant basics in dealing with geodata and geomedia. ESD practitioners should always be able to access further details within all materials, appropriate to their background and level of knowledge. Guidelines and quality criteria for the creation of ESD and e-learning materials (e.g., NP BNE, 2022; University of Toronto, 2022) allow for the development of appropriate and user-centred materials in terms of content, design and structure (Table 2). These overlap with criteria generally used in the development of applications in terms of usability, accessibility and utility, user-friendliness and user-onboarding. Last but not least, all materials should ideally be available as Open Educational Resources (OER), in line with sustainability requirements in teaching (Muuß-Merholz, 2020).

Importantly, the survey results show that interest, motivation and awareness regarding the suitability and importance of using digital geomedia in ESD must first be created (Section 4.1). This must take place prior to developing the necessary skills.

Table 2: Selected recommendations for the design of materials that support or guide the use of digital geomedia in ESD (adapted from Hamilton, 2016; Hennig et al., 2022; Munger, 2016; NP BNE, 2022; Renz et al., 2014; Wilber, 2018; Wrightsell-Hughes, 2015)

Criteria	Recommendations
Usability Accessibility Utility	Conscious and well-considered use and choice of language (no technical terms from the IT/GI domain)
	Conscious and well-considered use of colours, symbols, font type and size (title, subtitle, regular text etc.)
	Limited amount of text to read (<120 words at a glance), clearly structured with, e.g., bullet points
	Use of multimedia; generally not much text to read
	Intuitive, simple and appropriately structured graphical user interface (GUI)
	Avoidance of unnecessary details, elements and interactions
	Succinct presentation, with opportunities for accessing further information via interactions and links; little need for scrolling; Consideration of F/Z pattern of visual hierarchy
	Access to materials with online and offline use (possibility for download)

	Consistent use of structure and design throughout all elements of the materials
	Consistent use of corporate design throughout all elements and building blocks
	Attractive layout or design appropriate for the target group and domain
Joy of Use	Using a mascot to lead through the material
	Use of a grid design for the material compilation to easily understand the structure
	Simple, concise instructions
	Variety and combination of different media
	Ability to access further information (if required/interested)
	Clear and readily understandable structure
User-Onboarding	No registration or login, open access (i.e. Open Educational Resources, OER)
	Short personal welcome
	Presentation of the project/product, through e.g. multimedia files (short video/audio files); limited or no text at all to read
	Context-related instructions that are optional and available with varying scope and depth (short explanations with hyperlinks to further information)
	Highlighting of relevance for ESD, e.g. benefits of using and integrating digital geomedia in ESD

5 Conclusion

Even though abundant possibilities to include digital geomedia in ESD initiatives and activities already exist, the use of digital geomedia is still limited, and the existing potential is not being fully exploited. To enhance the application of digital geomedia in ESD, it is important to address several key points, including clarification regarding the practical implementation of digital geomedia in ESD, identifying obstacles and opportunities for their effective use, and developing strategies and solutions to overcome barriers.

To assess these hindrances, a survey was carried out among organizations involved in ESD in Germany, Austria and Switzerland. The results of the survey show that while ESD practitioners do generally see great potential in the use of digital geomedia, they actually make only limited use of them, focusing on very few possibilities, such as location-based games (e.g., Geocaching, Actionbound).

The use of digital geomedia in ESD can be promoted, supported and improved through a number of measures, notably the provision of information, an overview of concrete approaches, and examples of the targeted integration of digital geomedia in ESD. Measures for this encompass public relations and dissemination activities, including knowledge transfer in different formats. Of particular relevance is the development of a specific community (i.e. with experience in the use of digital geomedia in ESD) that can promote the approach among

their peers and stakeholders. Suitable training for ESD trainers in the competent handling of digital geomedia is also key. The development of training materials should take into account existing guidelines and quality criteria from the education sector (e.g., eLearning, adult education), and from the application development sector (e.g., criteria regarding usability, accessibility and user onboarding). Finally, the provision of more and appropriate materials to carry out ESD activities using geomedia should be addressed, as should sharing such activities via portals such as Sustainicum, BNEBox, PlayGreen, or ESDplus (https://esdplus-zgis.hub.arcgis.com/pages/anwendungsbeispiele), which is dedicated specifically to ESD.

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