Potential of Learning Labs to Improve the use of Digital Geomedia in Education. The Use Case iDEAS: Lab Discussed using the Example of the ESDplus Project

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Abstract: Digital geomedia and thus, the use of digital, spatial tools such as, online-maps and satellite images, are playing an increasing role in all educational areas and contexts. This refers, first, to their use in all types of (school) subjects to improve learning efficiency (e.g., related to the Spatially Enabled Learning concept) and, second, to building digital and geomedia skills, among learners (e.g., required by the Basic Digital Education approach and the Spatial Citizenship concept). This is highlighted by the growing importance of geomedia skills for our private and professional lives, which are closely linked to digital geomedia skills and STEM subjects (Science, Technology, Engineering, and Mathematics). To develop geomedia skills in young people and the public, we need not only appropriate teaching and learning approaches and methods, but also well-trained educators. However, this demand is not yet sufficiently considered. Here, learning laboratories (learning labs), i.e., those with a focus on the use of geomedia, as innovative spaces that support non-formal learning and promote new teaching methods, play a crucial role in closing this gap. This is highlighted by the increasing number of such facilities located, among others, at universities. While learning labs can contribute to promoting the use of digital geomedia, it is still unclear how exactly they can contribute to educators using digital geomedia more effectively in educational activities. This question is answered using the example of the ESDplus project. Based on the use of methods such as an online survey and transdisciplinary workshops, the project ESDplus aims to understand the situation and demands of educators involved in Education for Sustainable Development (ESD) in terms of using digital geomedia. The results not only helped create user-centered teaching and training materials to support educators using digital geomedia in ESD but also allow us to discuss how learning labs can meet the identified ESD educators' demands. This is done by the case of the iDEAS:lab, the learning lab of the Department of Geoinformatics-Z_GIS, University of Salzburg (Austria) focusing on the different objectives

around education in terms of teaching and as well as educational research. The results highlight the relevance of learning labs, to improve the use of digital geomedia in education. This is because of its flexible and open setting to combine analog methods and digital geomedia, the provision of learning activities for young people and training initiatives for (future) educators, and the building of communities of people interested in using digital geomedia in education. This also includes research activities around education and capacity building.

Keywords: geomedia; non-formal education; education for sustainable development; geoinformatics

1 Introduction and Research Questions

There is a growing need in education to equip learners with skills such as innovation, collaboration, problem-solving, critical thinking and digital literacy. In today's world, they are needed in both private life and the labor market. Additionally, sustainable development (i.e., sustainable development goals SDGs, Environmental, Social, and Governance ESG) and the ability to translate and implement regulations and policies in a business context are highly sought-after professional skills in today's workforce [1-3]. For this, the use of digital geomedia and the building of geomedia skills is an aspect that should not be underestimated [4].

Digital geomedia refers to digital geoinformation as well as digital tools, including geographic information systems (GIS) and other tools and applications that refer to all means of analyzing, displaying, and visualizing geodata [5-7]. Examples are web-mapping tools (e.g., Google Maps, Scribble Maps), virtual globes (e.g., Google Earth), location-based games (e.g., Geocaching, ActionBound), and data-capturing apps (e.g., GPS-Essentials, Esri's ArcGIS Survey123, Geo Tracker). Digital geomedia also includes data visualization tools like interactive web maps, story maps and interactive dashboards, and tools to access spatial data like satellite imagery, open government data and volunteered geographic information [8].

The use of digital geomedia in education can be viewed from different perspectives. On the one hand, it refers to integrating digital geomedia into educational contexts, such as various (school) subjects. This brings numerous advantages as underlined by the approach of Spatially Enabled Learning (SEL) [9]. These include enhancing teaching effectiveness, introducing new learning dynamics through the provision of spatial context and representations, as well as the possibility that location, i.e., space, can serve as an interface to additional information. Moreover, it can contribute to changing the perceptions of environments and thus, provide a great opportunity for a more optimized learning experience [10]. These advantages stem from digital geomedia's ability to provide

a spatial context and facilitate dual coding, i.e., the simultaneous combination of verbal and visual information, which enhances memory and comprehension in learning scenarios. There is also the possibility of easily accessing, using, and visualizing multidimensional data even from different sources, facilitating the contextualization of observation and simulation data, and enabling real-time feedback. Ultimately, this fosters critical thinking, encourages transformative actions among participants, and supports research and educational projects focused on ecology and sustainable development. It also enhances site awareness and awareness of environmental and ecological issues, sustainability practices, and community engagement [9] [11-14].

On the other hand, using digital geomedia in education relates to developing geomedia skills in the learners. These skills are closely related to and overlap with digital skills and align with the concept of Spatial Citizenship. This concept highlights for today's society the need for technology and methodology competencies to handle geomedia, competencies that enable reflection and reflexibility regarding geomedia, and competencies in communication, participation, and negotiation with geomedia [15] [16]. Here, the development of geomedia and digital skills is tied to the growing demand for more STEM education (i.e., education regarding the subjects of Science, Technology, Engineering, and Mathematics and focusing on problem-solving, critical thinking, innovation, and applying knowledge to real-world challenges). The connection between STEM education and geomedia and digital skills is symbiotic [17-19]: Both are crucial for the future, as they are essential for innovative developments to improve our quality of life and promote sustainability [20].

Given the potential of digital geomedia for education – i.e., regarding its integration in different subjects to improve education and learning outcomes as well as improving geomedia skills of the public – there is a need to work on and develop new and innovative teaching and learning approaches, and to promote the development of underlying competencies and pedagogical innovations [1-3]. This includes the building of skills among teacher training students, teachers, and other educators to use geomedia in education in a competent way, which is still little addressed, among others, in teacher education [21] [22].

To meet the above needs, there are several options. These include educational and capacity-building projects focused on geomedia (e.g., Spatial Citizenship [16]), as well as citizen science and school-based research projects (e.g., YouthMap5020 [23]). Additionally, new learning opportunities and practice, such as learning laboratories (learning labs) in the context of museums, libraries, Fabrication Laboratories (Fab Labs), and coding clubs, which have emerged recently, can play a key role [24-26].

Learning labs are innovative spaces, i.e., environments – physical, digital, and human – that support non-formal learning activities (e.g., outside traditional classroom settings) and can generate pedagogical innovations and innovative

learning scenarios to develop the required competencies [1, 27, 28]. These labs address STEM subjects such as Biology, Chemistry, Informatics, Mathematics, and Physics [27], and play a key role in education using digital geomedia. The growing interest in the use of digital geomedia in education and in learning labs is reflected in the increasing number of such facilities. Examples in Germany and Austria are Lernlabor ELLSI Augsburg (Technical University of Applied Sciences Augsburg), Lehr-Lern-Labore, Lernwerkstätten und Learning-Center und GEO Lehr-Lern-Labor (University of Münster), Lehr-Lern-Laboren LLL (University of Würzburg), Heidelberger Life-Science Lab at (German Cancer Research Center Heidelberg), GoetheLab (Goethe University Frankfurt), Lernlabor VisualStoryMapping (University of Bonn), Geomedien-Lernlabor (University of Kaiserslautern-Landau), Mitmachlabore Graz (University of Graz), Educational Lab at Lakeside Science and Technology Park (Klagenfurt), and iDEAS:lab (Paris Lodron University of Salzburg).

To fully understand and leverage the potential of learning labs, concerning supporting the use of digital geomedia in education, there are several open questions:

(1) What requirements do educators have to be properly prepared to use digital geomedia in education?

(2) How can learning labs meet the identified demands?

(3) How can the existing potential of learning labs be better utilized?

These questions are answered by evaluating the characteristics and offers of learning labs in general and the iDEAS:lab in particular, considering the demands identified within the framework of the ESDplus project, a project focusing on the promotion of digital geomedia use in education.

Founded in 2016 and maintained by the Department of Geoinformatics-Z_GIS of the University of Salzburg (Austria), the iDEAS:lab (https://ideaslab.plus.ac.at/) is an interactive laboratory for research-based learning at all levels in the context of geoinformatics experiments, addressing the public. Equipped with innovative Digital Earth technologies, iDEAS:lab's focus is on the interface between real and virtual worlds. It offers didactic preparation of geoinformatics research on socially relevant topics like digital skills, Artificial Intelligence, Earth observation, climate change, and epidemiology.

The ESDplus project (https://esdplus-zgis.hub.arcgis.com/; running from 4/2023 to 9/2025) is funded by the Earth System Sciences Funding Program of the Austrian Academy of Sciences. Its goal is to increase the use of digital geomedia in (non-formal) education for sustainable development (ESD). For this, ESDplus focuses on creating teaching and training materials to help educators use digital geomedia effectively in ESD. These materials are developed based on a clear understanding of how digital geomedia is currently used in ESD, including the benefits and challenges that ESD educators face, and how these can be addressed.

An intensive cooperation with ESD educators, such as those from Berchtesgadener Land Biosphere Region (Germany) and Lungau Biosphere Park (Austria), is a key issue to learn about the aspects mentioned above.

2 Workflow and Methods

Various methods were used to answer the above questions (Figure 1): literature and Internet review, an online questionnaire for ESD educators, transdisciplinary workshops to evaluate and discuss prototypes of the ESDplus teaching and training materials to be developed, and the well-established Metaplan method (a visual facilitation technique in which participants write ideas on cards, which are then grouped and discussed).

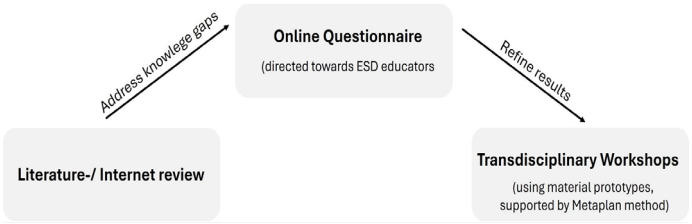

Figure 1
Workflow and methods used to learn and understand ESD educators' needs regarding the use of digital geomedia in ESD

These methods – described in more detail below – provided insights into the requirements of ESD educators regarding the use of digital geomedia in ESD. Now, taking the characteristics and offers of learning labs and the iDEAS:lab into account, allowed us to assess how learning labs can contribute to meeting ESD educators' needs and further improve the use of digital geomedia in education.

The literature review included the analysis of articles on topics like (non-formal) education, ESD, use of (digital) geomedia in education and ESD, geomedia skills, etc. In addition, the Internet was searched for websites of organizations performing ESD, particularly those using digital geomedia, and web portals listing examples of using digital geomedia in ESD. The findings from the literature and Internet review served as the basis for the development of a questionnaire aimed at ESD educators.

The online survey for ESD educators was conducted in the fall of 2023 and late winter of 2024. The questionnaire was created following principles of empirical social science research [29]. Table 1 shows its 14 closed and open questions, all of which are optional.

Table 1
ESDplus questionnaire and its questions

Question		**Question type**
1	Organization name	Open - short free text
2	Assessment of the use of digital geomedia in ESD per se	Closed - 5 point choice
3	Level of use of digital geomedia in ESD (1: none to 5: high)	Closed – array
4	Examples of the use of digital geomedia in analog ESD	Open - multiple short text
5	Familiarity with terms and concepts related to digital geomedia	Closed – array
6	Opportunities to support the use of digital geomedia in ESD	Closed - multiple choice (incl. possibility to add further aspects as additional open question)
7	Activities carried out related to digital geomedia	Closed – array
8	Topics suitable for using digital geomedia in ESD	Closed - multiple choice
9	Opinion on the use of digital geomedia	Open - multiple short text
10	Barriers regarding the use of digital geomedia use in ESD	Closed - multiple choice (incl. possibility to add further aspects as additional open question)
11	Best practice examples related to digital geomedia use in ESD	Open - multiple short text
12	Sources of information regarding ESD	Open - multiple short text
13	Added value of digital geomedia use in ESD	Open - long free text
14	Email to send results (in the case of interest)	Open - short free text

The online questionnaire was implemented using the online survey tool LimeSurvey (https://www.limesurvey.org). It was sent via email to organizations carrying out ESD across Germany, Austria, and Switzerland, such as protected areas, (natural history) museums, environmental education centers, learning labs, nature conservation associations, zoological gardens. This email included a request to share the survey with other organizations involved in ESD. All valid responses were identified (i.e., responses with at least one question). The answers to the closed questions were analyzed statistically using R in the integrated development environment RStudio. The answers to the open questions were analyzed using inductive category formation from qualitative content analysis according to Mayring [30] [31] and the QCAmap application (https://www.qcamap.org/ui/de/home).

Considering the survey findings, six workshops with 6-10 participants each were held in winter and spring 2024. Participants came from various regional ESD organizations, including the project partners (Austrian Biosphere Park Lungau; German Biosphere Region Berchtesgadener Land). During the workshops,

problems and advantages of using digital geomedia in ESD were identified. This occurred based on the use and discussion of the prototypes of the ESDplus teaching and learning materials. The Metaplan method was used to support the discussions on the prototypes and to generate suggestions for their improvement.

3 Results: Situation and Demands Identified by ESDplus

3.1 Survey Findings

The ESD educators' survey led to 83 valid responses. The answers show that about one-third of the respondents have not yet used digital geomedia in ESD (26 respondents). Only 4% use digital geomedia extensively in ESD (3 persons); 39% use it to some extent (32 persons); 27% did not answer the question (22 persons).

Educators' attitude towards the use of digital geomedia in ESD

The attitude of educators towards the use of geomedia is as follows (Figure 2): Even though 83% of the surveyed prefer to use traditional, i.e., analog geomedia in ESD and 26% of the respondents see digital geomedia as only partially suitable for ESD, 63% of the respondents see great potential in the use of digital geomedia in ESD. However, 40% outline that they consider extensive training as a prerequisite for ESD educators; 57% consider a targeted integration of digital geomedia into ESD to be key.

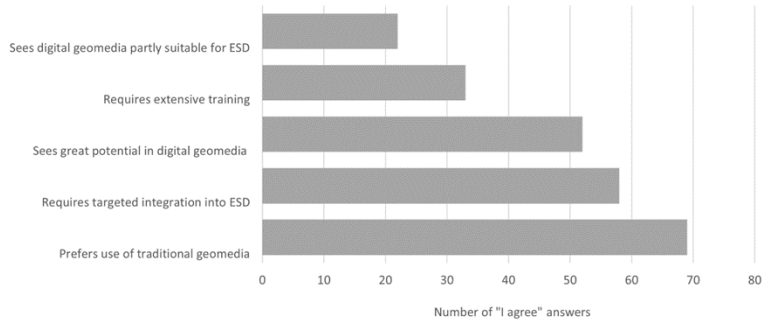

Figure 2
Agreement on selected aspects using digital geomedia in ESD (N=83, multiple choice)

The limited awareness of and access to using digital geomedia in ESD is also stressed by Figure 3. Only about half of the questionnaire respondents give concrete examples of benefits related to the use of digital geomedia in ESD, topics suitable from their point of view for using digital geomedia in ESD, traditional/ analog ESD activities that can be implemented with digital geomedia, and best practice examples of using digital geomedia in ESD.

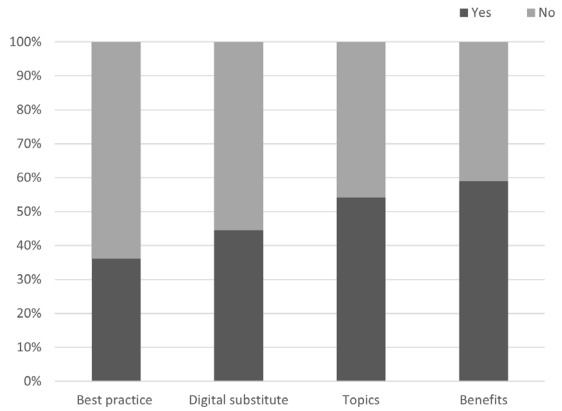

Figure 3

Percentage of respondents who could or couldn't name best-practice examples, examples of traditional/analogue methods that can be substituted using digital geomedia, topics suitable to be handled using digital geomedia, benefits related to the use of digital geomedia (N=83)

Barriers and options for support from the educators' perspective

Among possible barriers and options for supporting digital geomedia use in ESD, one key issue stated by educators is the provision of proper information, i.e., giving/ having an overview, and the availability of training possibilities (Figure 4). In the context of the open questions on barriers and support options regarding the use of digital geomedia in ESD, the respondents could also name other aspects that are central in their opinion. Here, they underlined the following barriers: per se better suitability of analog methods for ESD, availability of staff, the time needed for preparation and implementation of activities using digital geomedia, missing overview and understanding of the use of digital geomedia in ESD, financial issues, the lack of pedagogical concepts or pedagogical connections to the employment of digital geomedia in ESD, no relevance for the target group, the need for complex training, the thematic unsuitability of digital geomedia for the established ESD programs, and (missing) acceptance of using digital geomedia. In terms of support options, respondents outlined the following: availability of specially trained staff, the provision of background information, a suitable time frame for the integration in ESD activities, the availability of appropriate financial resources, integration into existing (digital) offers, presentation of practical examples, and ensuring good suitability of the solutions.

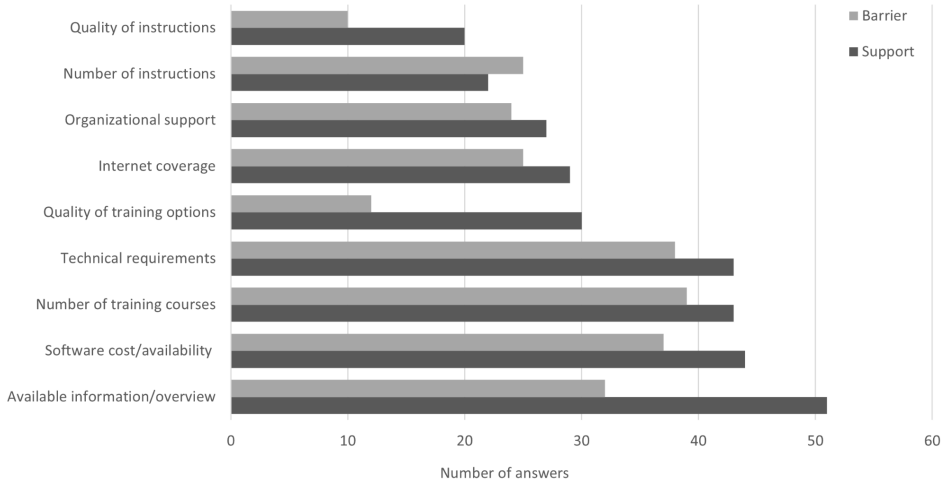

Figure 4
Barriers identified and support required using digital geomedia in ESD (N=83; multiple choice question)

3.2 Workshop Findings

The workshop results revealed key aspects to be considered when designing and implementing teaching and training materials for using digital geomedia in ESD. They refer to content and structure as well as design. The findings are consistent with experiences from fields like user experience (UX) including usability and accessibility, joy of use, user onboarding, participation, adult education, and eLearning (Table 2). More details are provided in [14] and [32].

Table 2
Identified requirements regarding ESDplus material, content structure and design

Criteria	Examples
usability, accessibility [23][33]	Suitable colors, symbols, language (including corporate design)
user onboarding [34][35]	Attractive, motivating, gentle first contact with the materials
participation [36][37]	Addressing people's motivation
eLearning [38][39]	Relevance of layout and design, use of multimedia
adult education [7][40]	Use, integrate existing knowledge

During the workshops (based on using and discussing prototype teaching and training materials), participants highlighted several aspects that are crucial for supporting and promoting the use of digital geomedia in ESD. These findings

focus on educators' motivation, interest, knowledge, and skills and refer to findings presented in the literature, particularly from the fields of participation and adult education [7, 22, 41, 42]. Key points are: (i) the use and combination of analog methods and digital geomedia in ESD activities and showing how integration can look and work, (ii) focusing all information and instructions related to the use of digital geomedia on ESD and its objectives, (iii) providing insights into advantages and background on the use of digital geomedia in ESD (including a general overview of tools, data, applications, and interesting and exciting examples, i.e., best-practice examples), (iv) offering information to dispel doubts among ESD educators regarding the use of digital geomedia and to increase their awareness and motivation, (v) addressing ESD educators' motivations and interests and existing background and skills and build on it, (vi) building topic- and domain centered skills supporting and enabling exchange and networking among educators etc. , and (vii) focusing on practice instead of theory, particularly showing how to use digital geomedia to address ESD objectives – without an overly obvious focus on building digital and geomedia skills.

With these results in mind, the question is how these needs can be addressed in the framework of learning labs. This is discussed using the iDEAS:lab use case mentioned above.

4 Discussion: Educators' Demands and iDEAS:lab's Potential

Learning labs - being physical, digital and human spaces in an innovative setting - fulfill different tasks and pursue different objectives around education with respect to teaching and training as well as educational research [43]. They are structured around three intertwined dimensions: spaces, activities, and communities [1] [27]. Taking these points into account (i.e., spaces, activities, communities, and educational research), the following discussion looks at the needs of educators identified through the ESDplus questionnaire and workshops, aiming to understand and assess how learning labs, like iDEAS:lab, can support the use of digital geomedia in ESD.

4.1 Spaces

A central aspect for the activities in learning labs is their premises, including their equipment and the setting itself. This peculiarity of learning labs is highlighted, for example, by Christidou et al. [44], who explained that children are not necessarily willing to participate in an activity when it takes place in a school setting, unlike when it is done outside the classroom.

Learning labs strive to enhance the learning process by providing learners with opportunities to actively engage with content and tools and providing them with access to supportive peers and knowledgeable mentors [27]. At that (modern) learning lab work is based on a combination of traditional methods and tools as well as digital media, including digital geomedia [27].

Thus, learning labs are characterized by the possibility of being in line with different contemporary learning approaches (Table 3), such as collaboration-based learning and connected learning. Not only does this improve learning efficiency, but it also enables prepared learners to face the challenges of a complex global world and gain the skills they need to succeed in a rapidly changing world while pursuing their passions and inspiring one another [27].

This addresses the need to build 21st Century skills, such as critical thinking, creativity and innovation, collaboration, communication, information, media and technology literacy, flexibility, and social skills, which are all critical issues for the 21st Century workforce and required in today's working world [45]. Furthermore, these aspects are considered to support actions for sustainable development [2] [3].

Table 3
Selected cotemporary learning approaches [46, 27, 47, 48, 49, 50, 51, 52]

Approach	Description
Active engagement	Learners actively participate in tasks, experiments, or collaborative activities; they do not passively receive information
Hands-on learning	Learners interact with real-world materials, technologies, or systems to apply knowledge and skills in a practical context
Exploration & Experimentation	Learners have the freedom to explore, test ideas, and experiment without the pressure of traditional classroom constraints
Collaboration-based learning	Learners participate in group work, peer-to-peer / peer collaboration, fostering teamwork, communication, collective problem-solving, etc.
Connected learning	Learners can build skills and knowledge to pursue personal interests or passion in an environment that provides support from others and can link this learning and interest to academic or career success or to civic Engagement, i.e., learning that is interest-driven, socially relevant
Problem-based learning	Learners engage with real-world problems, fostering critical thinking and problem-solving skills
Student-centered learning	Learners are at the center of all considerations at every stage of design, implementation, and evaluation
Project-based Learning	Learners work independently on tasks, develop solutions in teams, and reflect on their actions
Inclusive learning	Learners not only acquire technical competencies but also enhance their social and personal skills through the collaborative learning process, fostering values such as equality, solidarity, cooperation, and tolerance

With its two particularly designed and equipped rooms regarding GI (geoinformatics), the iDEAS:lab offers a specific learning setting (i.e., GI Workshop and GI Experience; https://arcg.is/1Kbm5e1). While the GI Workshop room is equipped with five working places including relevant software and Internet access (e.g., for collaborative group work), a presentation place with a smartboard-like touch screen, and three workstations with 10 large touchscreens (e.g., for pop-up presentations and group discussions), the GI Experience room is equipped with six GI experience stations (https://arcg.is/10v1fa2), a presentation station, and two workstations with touchscreens. Thus, as an open and flexible environment or space, iDEAS:lab, supports, e.g., interactive, hands-on, and experiential learning, promotes active learning, creativity, and collaboration, and is therefore a valuable tool in education and skill development.

With this, iDEAS:lab meets several aspects stressed by ESD educators in terms of using digital geomedia in ESD. The in-situ setup offers the possibility to combine analog, i.e., traditional, and digital geomedia in an open workshop setting (issue: preferred analog methods in ESD). Since the lab is part of the university, different teaching and learning environments using and/or addressing digital geomedia can be tested and evaluated based on new learning concepts like Spatially Enabled Learning (issue: pedagogical connections to the employment of digital geomedia in ESD; [9]). By using geoinformation as a conceptual backbone, the potential of geomedia can be demonstrated on the fly (issue: perceived unsuitability of digital geomedia for the established ESD programs) and illustrated (issue: presentation of practical examples, ensuring good suitability of the solutions).

4.2 Activities

Activities in learning labs play a central and increasing role in non-formal education, which is becoming ever more important and receiving increasing interest [44] [53]. Non-formal education refers to planned and structured programs and processes that impart knowledge or skills while taking place outside the formal and structured system of learning that occurs within established institutions like schools, colleges, and universities, and which follows a set curriculum and is guided by specific educational standards and objectives. Further, non-formal education is characterized by a more flexible, learner-centered approach that adapts to the unique circumstances of learners without the constraints of exams or rigid schedules, but offering a diverse range of learning experiences tailored to meet individual and community needs [44] [54-56].

With non-formal education achievements being usually difficult to certify (i.e., not leading to officially recognized qualifications), even if their social recognition is increasing, it helps to bridge the gaps in education systems. It plays a significant role in the education of young people, vocational training, continuing education for adults, promoting lifelong learning, and professional development. It also

includes community building or personal enrichment courses, each tailored to specific learning needs, interests, and motivations [44] [54-56]. As a complement to formal education that aims to improve a range of skills and competencies (including practical knowledge and skills for the real world), non-formal education is considered to play a crucial role in modern society. Especially, the need to meet the continued global demand for STEM-related activities has led to increasing recognition of the value of non-formal science learning [57] [58].

iDEAS:lab offers opportunities not only for school-student related education, but also for the education of students and teacher training students as well as the training of teachers, educators, and others. Regarding school-student related education, there are different modules (https://arcg.is/1nPHiX2) that are carried out on-site, online, or at other locations. The iDEAS:lab website serves as a platform to provide eLearning training materials, information and instructions (https://ideaslab.plus.ac.at/pages/6ea8804eddaa40efb7acfd911562b2f5).

With these offers, iDEAS:lab addresses many of the ESD educators' demands. This refers to the call for appropriate information, instructions to implement one's own activities and training initiatives to be enabled to conduct one's own activities. Such materials are not only available online but also can be leveraged by participating in-person at the different activities. This also addresses other needs, which can increase interest, knowledge skills, motivation, awareness, and acceptance: In the framework of the iDEAS:lab workshops and hands-on activities, many of the above-stated demands and needs of ESD educators can be addressed, demonstrated, and discussed in an open setting regarding pedagogical and methodological innovation [1], e.g.: (i) use of freely available online tools (demand for affordable software), (ii) demonstration of in-situ use of geomedia (demand to address its potential and demand to demonstrate use case scenarios in ESD) , (iii) presenting underlying geomedia pedagogies driven by the academic background (demand for pedagogical concepts), and (iv) providing tutorials and materials in addition to the on-site activities (demand for support)

4.3 Communities

Following Sanchez et al. [1], one of the biggest challenges in the design and implementation of learning labs is the establishment, development, and maintenance of their learning community. As the ESDplus findings underline, there is a need for more information as well as to raise interest and motivation raising, and build awareness among educators regarding the use of digital geomedia in ESD. For this, the existence of an appropriate network and community is key. This enables and supports exchange with colleagues and others working and being interested in this field and learning from their experiences [36] [41]. Thus, networks and communities of learning labs are aimed at learners and educators.

While digital networks and communities provide essential platforms for information exchange and collaboration, personal contact between peers remains key. This can create additional common ground and trust for the according topic [42] [59]. It is possible to turn to others for help [41] [60] and the existence of a community itself and the opportunities that communities open, can motivate people to engage with topics that seem less attractive to them [36]. In a nutshell, this can help to improve knowledge about the use of digital geomedia in ESD, increase interest, acceptance, awareness, and to reduce rejection.

Considering this, iDEAS:lab serves as a contact point between different actors and stakeholders involved or being interested in the use of geomedia in education. Due to its belonging to the Department of Geoinformatics (Z_GIS), this refers, among others, to experts in the field of geoinformatics (GI) and GI pedagogies as well as educators.

To build a corresponding community and to benefit from the above points, iDEAS:lab can benefit from being part of networks, like MINT labs (e.g., MINT:labs Science City Salzburg) and other networks like OeAD young science (Austria's Agency for education and internationalization). Through Z_GIS, iDEAS:lab also profits from networks such as Cluster Mitte Lehramt (the local teacher initial training umbrella in central Austria combining universities and pedagogical universities) or the CIVIS Open Lab network (https://civis.eu/en/engage/open-labs). Finally, iDEAS:lab provides a comprehensive database on regional schools including teachers. With its infrastructure and the possibilities opened through Z_GIS, iDEAS:lab also addresses the need to support community building in terms of non-formal education and ESD (e.g., referring to organizations like protected areas, environmental stations, museums, zoological gardens, NGOs) [14].

4.4 Educational Research

With the described features and characteristics, learning labs can additionally serve for observation and experimentation, to rethink and enrich learning and teaching attitudes and practices, and thus encourage deeper understanding and skill development [1]. New educational approaches and teaching concepts can be tested and evaluated regarding the (respective) subject-specific didactic research [28] – including GI didactics [23]. This means that learning labs are also fundamentally relevant, in the context of educational research. This especially proves to be true for learning labs run by universities or research centers.

Here, iDEAS:lab is comprehensively supporting the ESDplus project and the related research. This refers to the use of the available rooms (i.e., due to the appropriate, flexible workshop setting), the building of an according community (i.e., due to the invitation of local ESD organizations to participate in the ESDplus

workshops) and the development of activities (i.e., development and sharing of teaching and training materials).

Another example to clarify the relevance of educational research in learning labs focusing on digital geomedia is the "Skills & Stories 4 Girls & Women" project. This initiative employed an iterative co-creation-based approach to STEAM learning experiences and education and engagement of young citizen scientists (STEAM: Science, Technology, Engineering, the Arts, and Mathematics). By sharing and discussing personally relevant stories related to their local environment, participants enhance their STEAM skills while identifying with the topic (ownership). Participants contributed to all phases of the process: from co-creation to data collection, workshop discussion, and the generation of outputs for local and regional policymakers. Besides geomedia skills, digital skills were emphasized. The research included a reflection of the methodology used, the conceptualization, as well as evaluation and critical reflection of the approach, and outlined recommendations for future reusability of the approach, considering and reacting to rapid technological innovation [61].

Additionally, iDEAS:lab staff engages in research aimed at making STEM initiatives, particularly those focused on digital skills, more accessible to the public and here especially girls and women. The relevance of this initiative is underlined by the assessment of workshops developed under the funding of the Austrian Federal Chancellor's Office through the project Skills & Stories for Girls & Women, Digital Self, and Digital Navigator. The findings highlight the importance of both quantitative and qualitative evaluation, as they reveal a clear preference for hands-on modules on contemporary topics, often in line with the newly introduced subject "Digitale Grundbildung" (i.e., Digital Basic Education) for lower secondary school classes (Sekundarstufe I).

For learning labs, support materials are also crucial; therefore, sharing these resources within the community, via the project platform or other e-learning platforms, plays an important role in sustaining collaboration and fostering a broader impact in education [61]. Here, related educational research and can be further supported by iDEAS:lab and related projects [14] [32].

Conclusions and Outlook

Digital geomedia is becoming increasingly important in education, on the one hand, to use it across subjects and, on the other hand, to build up digital and geomedia skills among the public. The prerequisite for this is that educators have the appropriate skills themselves. This demand is still not appropriately addressed. Here, learning labs can play an important role. But what demands do educators have regarding their ability to use digital geomedia in education? How can learning labs address the identified requirements? How can the existing potential of learning labs be better utilized?

These questions were answered using the example of the ESDplus project which, among other things, aims to understand the situation and demands of ESD educators regarding the use of digital geomedia in ESD. Applying different methods (e.g., literature and Internet review, an online survey, and transdisciplinary workshops), the needs of ESD educators were identified. Their addressing was discussed regarding the possibilities of learning labs with their characteristics of space, activities, communities, and educational research. For this, iDEAS:lab, the GI learning lab of the Department of Geoinformatics-Z_GIS at the Austrian University of Salzburg, served as a use case.

This revealed the importance of learning labs to more comprehensively integrate the use of digital geomedia in education, as they make it possible to respond in a variety of ways to the requirements of educators regarding the use of digital geomedia in education. The iDEAS:lab use case underlines the relevance of conducting educational activities and train-the-trainer initiatives in specially equipped and designed spaces, i.e., rooms to support contemporary learning approaches. Further, it includes the sharing of online materials such as instructions and tutorials to guide and prepare educators to use digital geomedia. Events and activities support community building. iDEAS:lab website and the use of social media channels help to spread the word about the possibilities and advantages of using digital geomedia in education, arouse interest and motivation, and reduce skepticism. This can contribute to increasing the use of digital geomedia in education and thus the use of innovative methods and tools.

Educational rresearch can provide new knowledge and insights into the use of digital geomedia in education. This is particularly needed also in terms of the need to create an appropriate GI didactic backbone. This will allow us to better exploit the potential of learning labs regarding the use of digital geomedia - as well as to use digital geomedia in education.

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