Discovery Trail
Systematic use of digital outdoor learning tool

Co-funded by the
Erasmus+ Programme
of the European Union

DISCOVERY TRAIL

Systematic use of digital outdoor learning tool

Handbook

Tallinn, 2024

NaturErlebnisPark SCIENCE EDUCATION CENTER
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This handbook is based on the work within the project 'Discovery Trail. Systematic use of digital outdoor learning tool'. Coordination: Dr Elina Malleus-Kotšegarov, TALLINN UNIVERSITY, Estonia. Partners: HELSINGIN YLIOPISTO, Finland; NaturErlebnisPark Science Education Center, Austria; ELLINOGERMANIKI AGOGI SCHOLI PANAGEA SAV VA AE, Greece.

The project 'Discovery Trail. Systematic use of digital outdoor learning tool' has received co-funding from the Erasmus+ program of the European Union (grant no. 2021-1-EE01-KA220-SCH-000024427). Neither the European Union/European Commission nor the project's national funding agency DAAD are responsible for the content or liable for any losses or damage resulting of the use of these resources.

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Table of Contents

Foreword about 'DISCOVERY TRAIL'

What are your thoughts when you see a young person walking in the park with a mobile phone in their hand? Do you suspect that the younger generation is so addicted that they cannot live without their screens for even one moment? Or do you consider it might actually be a learning exercise, connecting them deeper with the environment?

We work for a future where the last option is the prevalent one. Our project Discovery Trail has supported teachers in developing outdoor learning activities for teaching biodiversity. Those activities make use of smart devices as tools that enable taking guided learning out of classrooms and into where learning about biodiversity should really happen – the nature.

At the same time, the primary innovation within the Discovery Trail project is not the use of screens. Rather, it is the way we want to support the learning process. Based on insights from educational psychology, we propose methods that support the cognitive processes that lead to noticing and understanding the invisible connections that govern the environment and ecosystems.

These new teaching formats are not a fancy option, but represent a necessary trend. In the face of new global challenges, education must also change, offering knowledge and skills that are needed to cope in the transforming world. More than ever, we need to guide the focus of education on the sustainability of the planet and the well-being of our communities and societies, not just individual success.

Biodiversity is a crucial but rarely acknowledged component of human well-being. It surrounds us everywhere, but you need a trained eye to start noticing the intricate ways in which the web of nature is woven together. However, once one has comprehended these connections, the impact of human behaviours on biodiversity becomes evident and creates a powerful impetus for behavioural change. Throughout the project, working with teachers and students in four countries, we have witnessed such moments.

We hope this guidebook provides you with the tools and impulse to integrate the Discovery Trail approach into a future-oriented education. Join us as we embark on this trail of discovery, where knowledge transforms into understanding, and understanding into meaningful change.

The team of editors

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See the **Discovery Trail project website** for details on the project, materials, and partners

Part I: Basic considerations of the Handbook

Education for sustainable development (ESD) in a changing world – an introduction to the DISCOVERY TRAIL project

Education for Sustainable Development

The word 'sustainability' was introduced in the 1960s, at a time of growing concern about the state of the environment (e.g. Roosa, 2008). Even before that, the term 'sustainability' was used in a number of contexts (Mensah & Casadevall, 2019). *The Limits to Growth*, a report by Club of Rome in 1972, was the turning point in relation to nature and environment (Meadows, 1972). In the 1980s, the term 'sustainable development' (SD) was used in the world conservation strategy (IUCN/UNEP/WWF, 1980). The strategy underlined that environmental considerations must be taken into account in all planning. The best-known report is probably the Brundtland Report (Our Common Future) of 1987, which defined sustainable development more broadly (Hajian & Kashani, 2021). It became rapidly well-known and popular, getting very many interpretations. Its aim was a universal vision for a better future for humanity and the report defined SD as a development where the current generation also enables future generations to live. This was an attempt to influence people's rethinking of the planet. It also included a call for a debate on values and standards of behaviour.

The term 'sustainable development' was redefined and refined in the Rio Earth Summit in 1992 (CBD, 1992) and Johannesburg 2002 (World Summit on Sustainable Development, WSSD, known also as Rio+10) (United Nations, 2002). After the United Nations Conference on sustainable development in 2012 (Rio+20), SD was raised as one of the five key priorities by the United Nations agenda (Mensah & Casadevall, 2019). The model of the 2030 Agenda was also established on the basis of the traditional SD approach, which divides sustainable development into three dimensions: the ecological, the socio-cultural, and the economic (e.g. United Nations, 2015). The sustainability and well-being of the planet rests on ecological diversity and biodiversity. Diverse knowledge is needed to understand this and to achieve this goal. Good education is one of the objectives of the 2030 Agenda. The Dasgupta report also provides guidance on how to sustain nature's capacity to function (Dasgupta, 2021). This report also stresses the importance of education.

Due to the long history of the concept of SD, its use, definition, and meaning have also changed over time (Mensah & Casadevall, 2019). Because the term is widely used, there is a risk that the concept is misunderstood or used as a cliché (Mensah & Casadevall, 2019). In addition Ukaga et al. (2011) claim that sustainability and sustainable development (SD) is often used as a theme, jargon, slogan, or paradigm by different parties. For that reason, knowledge and education is understood as a necessity. It soon became clear that without education, the intentions and aims of sustainable development would be impossible to reach.

This form of education came to be known as Education for Sustainable Development (ESD) or Sustainability Education (SE). In this book, we will use the concept of ESD. Today's critical environmental challenges, such as climate change and biodiversity loss, have made the importance of sustainable development even more apparent. The world is changing rapidly and at an alarming rate because of humans (e.g. Bachmann et al., 2020; IUCN, 2022). We need knowledge and education to tackle these nefarious problems (e.g. Hofman-Bergholm, 2018; Vesterinen & Ratinen, 2023). Conceptual changes are necessary, which could be achieved through well-planned educational interventions.

Education for Sustainable Development (ESD) is a holistic approach to learning that promotes individuals with the knowledge, skills, values, and attitudes needed to contribute to a more sustainable future (e.g. Wolff, 2022). Rooted in the principles of sustainable development, ESD seeks to empower learners of all ages to make informed decisions and take responsible actions for environmental integrity, economic viability, and social equity, both locally and globally.

At its core, ESD recognises the interconnectedness of environmental, social, and economic systems, understanding that actions in one domain can have profound effects on others. Therefore, it emphasises a multidisciplinary and interdisciplinary approach to education, integrating concepts from various fields such as science, economics, social studies, and ethics. By fostering critical thinking, creativity, and systemic thinking, ESD encourages individuals to explore complex issues, identify sustainable solutions, and envision alternative futures (Wolff et al., 2020).

Furthermore, ESD promotes active and participatory learning experiences that extend beyond the classroom and engage learners in real-world contexts. Through hands-on activities, experiential learning, community projects, outdoor education, and collaboration with diverse stakeholders, individuals develop practical skills and a sense of ownership over sustainability challenges (Tilbury, 2011). This experiential learning approach not only enhances academic achievement, but also cultivates empathy, cultural understanding, and a sense of global citizenship (Kolb, 1984; Oxfam, 2015).

In essence, ESD aims to cultivate a generation of informed and empowered individuals who are capable of driving positive change towards a more sustainable and equitable world. By integrating sustainability principles into educational systems and lifelong learning opportunities, ESD offers a pathway towards building resilient communities, promoting environmental stewardship, and achieving sustainable development goals for current and future generations (UNESCO, 2017: 2017).

Under ESD, several different educational forms (e.g. climate education and biodiversity education) can be distinguished that focus on a specific concept or aspect, such as climate change or the perception, understanding, or recognition of biodiversity.

Unfortunately, many educators and administrators have been frustrated and afraid to act. These problems should not be made children's responsibility. However, several encouraging examples have happened globally in schools, by teachers and students. The Discovery Trail project decided to try to tackle this nasty dilemma by concentrating on finding new types of opportunities.

Intentions of the Handbook

The challenges of our time are to find solutions that promote sustainable and future-oriented development to protect and preserve our environment for present and future generations. First and foremost, this means changing individual attitudes, values, and behaviours as well as social values. In order to achieve sustainable, consistent, and transferable behaviour change, it is necessary to understand the reasons for change, i.e. to internalise the causes, effects, and benefits of transfer (Heimlich et al., 2014; Palmberg et al., 2017; Wolff, 2022). When it is about protecting vulnerable complex systems, an understanding of the nature of these systems is the key mechanism to derive appropriate behaviours from a multi-perspective discourse. The aim of this DISCOVERY TRAIL (DT) project is therefore to develop effective interventions to promote a deeper understanding of complex systems (such as biodiversity) among all learners by linking the use of intelligent digital learning designs with current scientific research findings on pedagogical and didactic issues.

This Discovery Trail project handbook (also referred to as the manual or the white paper) presents some pragmatic actions to support teachers and non-formal education specialists in planning educational interventions that support deeper understanding about different aspects of global environmental challenges, such as climate change and loss of biodiversity. This handbook also provides guidelines on how to develop high-quality Discovery Trails for the Avastusrada platform. It is based on theoretical considerations on education for sustainable development, our project activities from interdisciplinary and international cooperation, as well as the findings of the pilot study. This manual has been published to allow us to share project experiences of using and developing Avastusrada as a learning platform to support students' understanding about biodiversity and to organise cooperation between teachers and non-formal education specialists to achieve more effective learning experiences. Bridging the gap between authentic learning environments and digital education is one of the key dilemmas of our school systems.

DISCOVERY TRAIL – project development, consortium, and general starting points for the implementation (combination of formal/non-formal learning)

The project consortium consists of a combination of universities, schools, and educational institutions (formal and non-formal education) who are dealing with the implementation of sustainable development goals in different ways.

Universities and schools (in this project, the University of Helsinki, Tallinn University, and Ellinogermaniki Agogi) are classified as formal education institutions. Formal education refers to the structured education system with a curriculum or programme that runs from primary school to university.

Some other educational institutions are classified as non-formal education centres. Non-formal education can refer both to curriculum-based aspects that support formal education and to structured programmes and processes of personal and social education for people that aim to improve a range of skills and competences. Non-formal education is what happens in places such as youth organisations, sports clubs, and drama and community

groups, where young people meet, for example, to undertake projects together, play games, discuss, go camping, or make music and practice drama.

The interdisciplinary research group SEEMIK at Tallinn University offers a wide range of possibilities to support the development of formal and non-formal education programmes (including developing the Avastusrada platform) and has extensive, long-term experience in evaluation and research in this field.

The NaturErlebnisPark Science Education Center offers education-oriented programmes that are organised in accordance with the respective curricula and educational plans, as well as further training activities for teachers and educators (a combination of formal and non-formal learning). In addition, a range of activities take place that enable education for sustainability outside the school context (non-formal education).

Informal education means a lifelong learning process, whereby each individual acquires attitudes, values, skills and knowledge from the educational influences and resources in his or her own environment and from daily experience. People learn from family and neighbours, in the marketplace, at the library, at art exhibitions, at work and through playing, reading and sports activities. The mass media are a very important medium for informal education, for instance through plays and film, music and songs, televised debates and documentaries. Learning in this way is often unplanned and unstructured. (https://www.coe.int/en/web/european-youth-foundation/definitions#).

Avastusrada was initially developed at Tallinn University. It is an open source platform that is used throughout Europe for the development of digital tools in various disciplines. The basic intention of the DISCOVERY TRAILS project is to develop high quality discovery trails to promote education for sustainable development both in and out of school. The combination of institutions and persons in the project consortium allows for an interdisciplinary and co-operative approach:

Tallinn University, Estonia – interdisciplinary research group SEEMIK – Educational psychologists, ecologists, communication science specialists.

University of Helsinki (UH), Faculty of Educational Sciences, Finland – Educational scientists, teacher trainers, and informal learning experts.

Ellinogermaniki Agogi (EA), Pallini, Greece. Private school and certified centre for teachers' continuing professional development, with a research interest in the fields of Inquiry-Based Science Education (IBSE), Project-Based Learning (PBL), and STEM education.

NaturErlebnisPark Science Education Center, Austria – with a focus on the development of innovative teaching approaches and practical research for cross-perspective science education (combination of formal and non-formal learning) and education for sustainable development.

The project consortium can therefore contribute different experiences for the development of high-quality discovery trails.

In the area of formal education

This builds on a well-established pedagogical concept that favours structured 'learning'. In formal education, teachers guide students to ensure that the knowledge that is to be taught in the current curriculum is transferred to achieve the specified learning objectives and educational standards. The educational formats are organised according to strict timetables. Students' performance must be evaluated on the basis of clear criteria (Project partners: Tallinn University, Estonia University of Helsinki and Ellinogermaniki Agogi)

In the area of non-formal education

Here, the learning process is organised with pedagogically planned and structured objectives to promote a range of skills and competencies that prepare for a self-determined life and participation in active citizenship. Learning is more centred on the needs of the participants, e.g. learning through personal curiosity, interests, and intrinsic motivation as well as social interactions. The approach is more holistic, based on personal experiences, social behaviour, and interactions and could also have an orientation to the curriculum (project partner: NaturErlebnisPark Science Education Center).

The combination of formal and non-formal education and an interdisciplinary project team should therefore create the basis for both the high-quality development of discovery trails and the promotion of education for sustainable development.

This group of people was formed as the project idea demanded various experiences in the field of education for sustainable development. All the project partners had experiences with creating interventions in the field of ESD and the interdisciplinary approach was seen as efficient when jointly planning various aspects related to an effective teacher training process and creating new trails on the Avastusrada platform in the participatory process.

Avastusrada was first created in Tallinn University, but then developed as an open-source platform that could benefit from trails created all over Europe. This helps educators and students to see the international aspect in learning similar topics and add value to the problems under discussion.

Supporting teachers and educators in non-formal institutions in ESD in DISCOVERY TRAIL – project

Students and pupils often form misconceptions about complex systems, such as the bio- and geosphere. This is well documented according to the critical literature review (Aboytes & Barth, 2020; Kaasinen & Myllyniemi, 2023). It has also become an essential question of educational debates in many countries.

Outdoor education is mentioned as one of the most efficient educational methods to promote ESD (Kervinen, 2020; Kaasinen & Myllyniemi, 2023). Many environmental issues are easier

to observe and understand in outdoor environments. Together with digital devices, the potential of outdoor environments can grow and increase. It has been shown that some digital interaction can increase motivation or help students to learn species, for example (e.g. Kervinen, 2020). DISCOVERY TRAIL project combines both outdoor education and digital learning.

Some teachers and education specialists might need encouragement to teach outdoors. Easy steps and guidelines will support them to develop their professional outdoor teaching skills and methods. The DT project provides actionable mechanisms that allow education professionals to think through their teaching towards conceptual change in a collaborative way when using digital outdoor learning platforms (e.g. Avastusrada). Digital platforms can also encourage both teachers and non-formal specialists to go out.

Students who will participate in a project by using the Avastusrada during their learning process will expand their understanding about biodiversity. In the long term, the project aims to raise awareness of the possibilities and threats in using digital outdoor learning tools to deepen understanding about concepts related to climate change and more specifically how to use the Avastusrada platform (www.avastusrada.ee/en) at different ages to support deeper understanding.

The overall objective will be achieved by the following specific sub-objectives:

- Raising awareness about climate change and inducing sustainable behaviour through prioritising different aspects of biodiversity in the target groups. The project's activities involve a number of teachers, non-formal education specialists, and students, who will be working together on the Avastusrada platform to understand better how concepts related to biodiversity develop and thus developing their own concepts.

- Supporting education professionals by providing new tools and methods to elicit conceptual and behavioural change, as well as for assessing its impact, in target groups relevant to the green transition (or degrowth economy), and to build a strong understanding about life-supporting systems.

- The activities linked with an objective will provide teachers and non-formal education specialists with a validated tool to elicit conceptual and behavioural change through the use of Avastusrada.

Outdoor education and development of high-quality nature trails

The Avastusrada platform is a tool which will support conceptual change, sustainable education, and professional development. It provides a multidisciplinary platform to create nature trails in different countries. During the DT project, educational psychologists have supported the understanding of psychological mechanisms underlying the changes in knowledge structure that help to better understand why digital outdoor learning tools may not be effectively used in some cases and how metaconceptual awareness can be better supported using prompting questions through Avastusrada. Ecologists have opened the concepts of climate change and biodiversity on a deeper level, while teachers and

non-formal education specialists have found methodological ways to support students' understanding through outdoor learning perspectives.

During the project DISCOVERY TRAIL, validated Avastusrada trails in various languages related to biodiversity concepts have been created and introduced to a wider teachers' community. The platform Avastusrada (www.avastusrada.ee/en) was created by Tallinn University and the university develops it continuously. The platform was initially created for non-formal educational institutions (nature schools, environmental educational centres), but more teachers from the formal education system are using it as an additional tool for outdoor learning activities. Although the platform gives opportunities to teach complex systems, combine disciplines, and connect tasks with surroundings, it is still rarely used for that. A research group from Tallinn University has analysed trails and questions that teachers and non-formal education specialists have created and found that educators who are using Avastusrada need more support to use it in a way that best supports the development of students' understanding.

In addition, Avastusrada gives an opportunity to help students to notice their own thinking – give metacognitive prompts and prompts about how to think about complex systems (see Tripto et al., 2016 for further information about metacognitive prompts). Environmental challenges relate to a wide range of different behaviours that have a complex relationship with the underlying environmental problem. It is therefore useful to equip people with concepts that are abstract enough to be transferable over different situations. This requires educational interventions that can enable active, effortful, error-prone, and slow processes of reviewing and re-constructing individuals' previous concepts, but at the same time, make this process as effective as possible. Digital outdoor learning tools can help teachers and non-formal education specialists to support the conceptual change process of students.

Education for sustainable development (ESD) in the context of biodiversity

Education for sustainable development (ESD) is a crucial approach to creating a sustainable future in terms of biodiversity. It is most importantly about familiarising people with the principles of sustainable development to conserve resources, promote social justice, and protect the environment. Above all, however, it is about transforming individual realities, social developments, and existing models of thought and behaviour. This paradigm transformation in ESD is an ongoing process that promotes the development of skills for critical reflection and future-oriented thinking. It is a process that requires self-reflection and critical analysis, which involves questioning assumptions, beliefs, and prejudices and incorporating different perspectives. This approach encourages openness, tolerance, and growth to work together towards a sustainable future.

The current ecological, economic, and social challenges require a comprehensive social change process towards sustainable development. Sustainable development is development that meets the needs of the present without compromising the ability of future generations to

meet their own needs, therefore all people must make a contribution (Brundtland Report). The following chapter provides an overview of how they can be taken into account in educational programmes.

At the level of educational approaches, it is necessary to understand the change at both an individual and collective level. These enormous developments require time, but also a certain speed to achieve the required progress. Therefore, various approaches that play a role in stimulating and promoting this process will be linked together to increase the chances of success.

The following objectives can be summarised for successful ESD:

Society must agree on a sustainable future and actively achieve it (**goal and vision orientation**). The active involvement of the population means active participation in democracy and responsibility for the future (**participation and democracy**). The fusion of social and technical innovations and the spreading of systemic innovations are crucial (**innovation and technology**). The success of future-oriented change can also be measured in the extent to which change models (**transition**) are used by different actors (models of change) and the extent to which organisational practices are established (**institutions and organisations**). For people to understand why development for sustainability is necessary, it is necessary to launch initiatives that raise awareness of this issue and support education in this regard (**awareness-raising and educational measures**).

Education for sustainable development plays a central role in promoting the sustainable and fair use of biodiversity and its conservation. UNESCO actively supports biodiversity education through initiatives such as the Education for Sustainable Development (ESD) agenda. Important approaches include integration into formal, non-formal, and informal education programmes. This will ensure that learners of all ages understand the importance of biodiversity and its conservation. To address the lack of awareness of biodiversity, many initiatives rely on information, communication, and education activities in their work. Educational approaches therefore provide an essential basis for raising awareness of transformation processes with regard to sustainable development.

Educational approaches

There are various approaches for making our society more sustainable and fit for the future. In the context of education, in recent years, these have included environmental education, education for sustainable development, and aspects of STEM education, which primarily relate to learning in the formal education system. These approaches have their origins in the fact that they refer to social concerns and problems and originally arise not only from a scientific, educational theory discourse (Scheunpflug, 2003). Overall, however, they claim to prepare people to be able to actively participate in social, scientific, and political decisions. The aim is not only to take steps to guarantee the ‘survival’ of our planet, but also to promote

individual developments that create the preconditions for a sustainable, fair, and humane society.

Educational approaches can essentially be summarised as follows:

Environmental education

The main purpose of environmental education is to raise awareness of the limits of our natural resources for people of all ages and to promote the willingness and ability to actively shape the environment. It focuses on the relationships between people and the environment, including the natural, cultural, technical, and social environment. It emphasises problem-oriented learning approaches (Künzli et al., 2010). The principles of environmental education are a global concern and are based on international documents and agreements of UNESCO and UNEP. Global problems are directly related to developments in society, with the focus being on global processes and their effects (Scheunpflug & Schröck, 2000). Environmental education is based on the principles of a lifelong learning process and is an integral part of high-quality education.

Education for sustainable development

The concept of education for sustainable development creates an awareness of the dimensions of sustainability and aims to raise awareness of the interdependencies and interconnectedness of our world. The focus is on a holistic educational approach that takes social, ecological, and economic aspects into account and creates a link between local and global perspectives and between the present and the future. It aims to promote sustainable thinking and action in all age groups, which is based on the global sustainable development goals (17 SDGs) of the United Nations. Originally, an approach was promoted that assumes that certain values and behaviours have a positive impact on sustainable development. This approach promotes values that experts have identified as sustainable, which is at the centre of ‘communication’ (Vare & Scott, 2007). In current discussions, however, an ‘emancipatory approach’, which corresponds to an open, process-related, and reflexive approach, is more popular. Here, ways of thinking and behaviour are not dictated by experts, but values and attitudes are discussed in different situations from a multi-perspective point of view. Instead of experts prescribing ways of thinking and behaviour, values and attitudes are discussed in different situations from a multi-perspective viewpoint. The focus here is on the ‘learners’, who continuously reflect on questions of sustainable development in different contexts. The aim is to promote an understanding of complexity, of constant change (in nature and science), for dealing with uncertainties and contradictions as well as for dealing with one’s own actions in a local and global context through critical examination (Vare & Scott, 2007). This should enable people to take responsibility for their actions, actively participate in creating a sustainable future, and develop creative solutions for alternative visions. Learners should be empowered to find sustainable solutions to global challenges. This includes, in particular, the conservation of biodiversity and the sustainable use of resources.

STEAM education (Science, Technology, Engineering, Arts, and Mathematics)

This educational approach promotes an understanding in the areas of STEM education (mathematics, computer science, natural sciences, and technology), as well as in the education of artistic and creative thinking in connection with scientific and technical education. The aim is to meet technical challenges with artistic, creative, and critical thinking, while also integrating aspects of art and culture. This broader perspective enables a holistic approach to the challenges of the twenty-first century and promotes innovation and creativity as well as an understanding and skills in these areas.

In many EU countries, this is a general concern that forms an important part of curricula in the formal education sector in the form of cross-curricular areas. In the context of biodiversity education, STEAM can contribute to developing a deep understanding of ecological relationships and finding sustainable solutions.

However, the inclusion of ESD topics in particular in curricula is not enough. Rather, it requires innovative, holistic teaching concepts that go beyond forming the basis for training the next generation of professionals. Students need to be empowered to recognise the interconnectedness of social, environmental, and economic systems, develop effective problem-solving strategies in the real world, and become aware of their own attitudes and mindsets.

Aspects of future-oriented education

The question arises as to how future-oriented education and learning can be organised to make a central and meaningful contribution to achieving a more sustainable and fairer world. Education that prepares people so that they are able to actively participate in social, scientific and political decisions is not only concerned with learning content, pedagogy, didactics, and the design of learning environments, but goes far beyond these aspects. In particular, it is aimed at learners of all ages – in the spirit of lifelong learning – to enable people to think and act sustainably. It also promotes education that relates to formal, non-formal, and informal learning. Learners of all ages therefore need a solid foundation of knowledge, attitudes, and competences to realise their potential and create conditions that prepare them for learning throughout their lives.

Forward-looking education includes the promotion of the following aspects:

Motivation and self-efficacy

People's experiences and behaviour are not only driven by rational factors, but also by 'basic psychological needs' (Deci & Ryan, 2000). In particular, this means that knowledge only has an effect on values, attitudes, and behaviour when emotions are triggered. The self-determination theory offers a meta-theory to explain human behaviour, whereby basic needs are determined by a certain autonomy, experience of competence, and social involvement. Every person has a certain tendency to develop personality, which is determined by the identification, internationalisation, and integration of values.

The positive perception of competence to act is closely linked to the development of a person's identity (identification). When learners realise that they can influence their own lives and the world around them through their purposeful actions (experience of competence), this has a positive effect on their well-being. In this way, they develop the ability to set goals, reflect, and act responsibly.
Interactions between the person and their environment over their lifetime are very dynamic. They reflect different internationalisation processes of norms that are subject to intrinsically and extrinsically influenced behaviour.
The development of motivation and self-efficacy always takes place in constant interaction with social contexts (integration of values). Contacts at various levels play a role in this, with enriching relationships and opportunities for interaction between students, teachers, parents and learning communities having an impact (Deci & Ryan, 2000).

Didactic aspects

The overriding principle is to appeal to positive emotions, which applies to all educational initiatives – regardless of the topic – and therefore also applies to biodiversity. A transfer of the self-determination theory into teaching practice is based on the phenomenon of different premises of motivation (Schiefele and Schreyer, 1994), which are orientated towards different qualities, are closely interrelated, and are based on a certain continuum. Depending on their characteristics, they can have a beneficial or hindering effect on motivation. Extrinsic motivation refers to external stimuli (such as school grades or compliments). Intrinsic motivation is based on the enjoyment of activities that are carried out for one's own benefit. With regard to long-term behavioural change, the promotion of intrinsic motivation is crucial, as it has an effect that is not linked to factors external to the learner and leads to better learning performance and a certain level of satisfaction.

When designing a sustainable learning environment for 10–15-year-old students, it is important that autonomous aspects are emphasised. Encouraging students to follow their own interests and set their own learning goals will increase their engagement and enjoyment of learning. If the value of a task is seen as significant for their own individual lives, they are more willing to get actively involved. As a further consequence, repeated involvement leads to different experiences, knowledge, and perspectives, which contribute to personal development and lead to a certain degree of identification with the learning content. In order to find a balance between internal motivation and external stimulation, it is therefore necessary to have clarity of purpose, visions of a desired future, and consistent steps to work on their realisation (Deci & Ryan, 2020).

System-oriented thinking – critical thinking, problem-solving

The complexity and interconnectedness of problems in the field of sustainable development (e.g. biodiversity) worldwide requires the acquisition of a 'systemic mindset'. This is not just about imparting knowledge (disciplinary, interdisciplinary, epistemic, and procedural knowledge), but about a holistic perspective. This should enable people to take responsibility for their actions and play an active role in shaping a sustainable future. Systemic thinking is

an interdisciplinary way of thinking that aims to recognise the essence of a system and understand the interactions between the individual parts and the overall context. Not only individual parts of a system are considered, but also the multitude of interactions and interrelationships within a system. Equally, not only a system itself is considered, but also networks and interactions in higher-level systems. In relation to sustainable developments, ecological, economic and socio-cultural aspects must be taken into account, as well as connections between local and global conditions and relationships between current and future events (Künzli et al. 2010). Linear thinking that is limited to simple cause-and-effect mechanisms is therefore not enough to understand complex problems and find sustainable solutions. Every element and every process in our environment is part of numerous subsystems (conglomerates) that are interlinked with larger systems. This interconnectedness results in a highly complex structure made up of many components with complex dynamics that are often difficult to explain and predict (Manderson, 2006). Systemic thinking therefore offers an approach to better understand complex problems and to uncover deeper causes.

Didactic aspects

Biodiversity is a very complex system. It includes knowledge about interactions, processes, and relationships within different ecosystems, as well as ecological, social, and economic components. In order to ensure an understanding of the well-being of current and future generations, it is therefore essential that solutions in the field of biodiversity also reach a broad consensus. An understanding of 'system competence' is important to find sustainable solutions to problems and to protect biodiversity. It cannot be assumed that complex issues are easy for learners to understand. It therefore makes sense to reduce complexity in lessons to initially promote relationships in a manageable context (**reduction of complexity**). However, the tasks should be designed in such a way that there is an overarching problem formulation in which individual contents can be linked (**linking of contents**). It is also important to ensure that different perspectives of stakeholders and experts (**multiperspectivity**) are presented. Learners are encouraged to ask questions, question assumptions, and find new solutions (**promotion of critical thinking**). Tasks that involve real-life examples and practical situations (**practical relevance**) also promote an understanding of systemic thinking. Systemic thinking goes far beyond individual subject areas (**interdisciplinary approaches**). The teaching process should essentially be based on repeatedly practising an understanding of systems, synergistic factors (interaction of individual factors and the interaction on an overall effect), analytical skills (logical thinking in the context of collecting information), the identification of certain facts, and the resulting predictions or modifications (considerations on adapting changed factual and practical skills). Achieving these objectives requires a continuous process that cannot be accomplished in a single lesson (cf. Mezirow, 1997). It is therefore important that learners are familiarised with systemic thinking at an early stage to be able to cope with the challenges of an increasingly interconnected world.

Transformative theories and processes

In order to master the challenges of the twenty-first century, citizens must be able to actively participate in social transformation processes. To do this, they need the ability to construct new or revised evaluations that can be used as 'guidelines' for future actions. In a transformative process, learners first realise that their own preconceived assumptions, perspectives, ways of thinking, and habits of thought are no longer valid. These arise from controversial discussions that are linked to different individual and social models, norms, and values. In a critical analysis, the self-evident is examined in relation to specific knowledge, convictions, value judgements, and feelings. Reflection is ultimately the starting point and condition for 1) considered action, 2) a changed interpretation of contexts and situations, and 3) enshrining what has been learnt in a permanent repertoire of interpretation and behaviour (cf. Mezirow, 1997). The frame of reference is repeatedly reflected upon in a critical, deconstructive, and transgressive manner in a multifaceted dialogue with several actors, which ultimately leads to a 'conceptual change' (Sterling, 2010; Mezirow, 1997).

Didactic aspects

Biodiversity plays a key role in the functioning of ecosystems, as well as in the provision of resources and biomass production, for example. Biodiversity has an impact on social, ecological, and economic areas in everyday life as well as on global contexts (**social relevance**). Tasks for learners therefore require specialised knowledge from different disciplines (**interdisciplinary approaches**) and include social and ethical components. This provides sufficient starting points for learners to become actively involved (**promotion of participation and willingness to act**) and to critically analyse existing structures, contexts, and norms (**critical reflection**). Complex questions are not easy to solve, as they often do not allow for a clear answer and must be considered from multiple perspectives. The provision of a multi-perspective debate therefore takes place with the inclusion of different arguments and values. The first prerequisites for a transformation in learners are that they are able to understand and respect different points of view as well as relate their own basic assumptions to scientific findings (Zeidler, 2014). Furthermore, learners must be aware that their own attitudes, norms, and options for action always exist in a certain social context (Zeidler, 2014). However, individual decisions for options for action not only depend on fundamental knowledge, values, and attitudes, but are often also made spontaneously depending on the current situation or the life span (Hentig, 2007). In a transformative process, learners should realise that their presuppositions, perspectives, ways of thinking, and habits of thought, which have arisen through previous interactions in an existing social context, may lead to inconsistencies regarding future social, ecological, and economic well-being. However, encouraging an individual or collective responsibility can contribute significantly to the promotion of sustainable development. This includes, for example, creating shared core values, promoting sustainable lifestyles such as sustainable production, sustainable consumer behaviour, and global value creation, as well as renewable energy, clean water, and sustainable cities.

Vision orientation – futures literacy

In order to be able to actively shape future systems in a complex world – in society, in politics, in nature – one must also understand the effects of one's own actions at an early stage. It is therefore important to recognise on what basis future scenarios are developed, how visions influence the future, and how they affect current actions. Future literacy includes the ability of people to strengthen their imagination for probable and desirable futures, a certain willingness to prepare for change, to acquire an openness to the new and the unknown, and to participate in the interaction of a 'reimagined' future. By practising systemic and forward-looking thinking, communities and individuals learn to better understand how to rethink current situations and shape different types of futures (Futures Literacy | UNESCO). The aim of the joint exchange is to recognise and reflect on unquestioned and sometimes erroneous assumptions about current and past systems, as well as to find and implement creative, diverse solutions. Such a participatory process (action learning) makes it possible to explore different ways of knowledge in a collective knowledge creation process, to renew choices, and to create an appreciation for changing futures (Futures Literacy | UNESCO). This way of thinking provides a tool to evaluate different options, diversify possible courses of action, and derive from them decisions that are made from a holistic and scientific perspective.

Didactic aspects

The preservation of Earth's various ecosystems, which encompass all life on the planet, including humans, necessitates certain processes of change and unfolds in a highly dynamic manner. Developing visions allows people to connect with their world. To imagine futures in different ways and become 'future-literate' (Miller, 2018), fundamental experiences, situational competence, inventiveness, creativity, and foresight are essential. Creative and innovative ways of thinking (**vision orientation**) are promoted in the implementation of classroom learning to develop motivating visions on an individual and societal level and to derive the resulting steps of implementation. Learners become aware that their perception of the present plays a central role in the future (Miller 2018). Learners are encouraged to actively contribute ideas and thus perceive that they can anticipate in different ways and thus also take responsibility for different futures (**participation orientation**). Learners are encouraged not only to acquire knowledge, but also to take concrete steps and reflect on them (**action and reflection orientation**). Reflection on options for action from different perspectives leads to a deeper understanding of the common process of knowledge acquisition (Miller, 2018). The learners take an active role in independently exploring connections, asking questions, and finding solutions to problems (**discovery learning**) and become aware of complex relationships (**systemic thinking**). The ability to imagine futures in different scenarios means that learners also contribute as active designers for a sustainable future.

Key takeaways:

The roles of educators are essential for fostering a dynamic and effective learning

environment. By integrating the following aspects of ESD in the context of biodiversity, the preparation of learners for an informed and proactive approach to the environment in terms of biodiversity can be significantly improved.

1. **Engagement and motivation:** Educational activities that promote experiential and contextualised learning emphasise learning in real-world settings, making the content more relevant and meaningful and fostering a deeper connection with nature. The dynamic outdoor environment can stimulate curiosity and a sense of adventure, making the learning experience more sustainable. This approach helps students understand biodiversity in its natural context and improves their ability to connect theoretical knowledge with practical applications.

2. **System-oriented thinking:** The combination of knowledge from different disciplines (interdisciplinary integration) such as biology, ecology, geography, and environmental sciences provides a comprehensive and holistic understanding of biodiversity and its importance for sustainable development. Practice-orientated teaching encourages learners to think critically and solve real-world problems. They learn to analyse environmental problems, assess the impact of humans on biodiversity, and develop sustainable solutions. It also addresses biodiversity issues at both the global and local levels, helping learners to understand the far-reaching impacts of biodiversity loss and the importance of local conservation efforts.
3. **Transformative theories and processes:** Ethical and value-based education is necessary to help learners instil values such as respect and a sense of responsibility towards the environment and to promote ethical choices and sustainable lifestyles. By including cooperation and teamwork in group activities and projects, learners are encouraged to work together. This enables learners to work together to analyse biodiversity issues and develop sustainable solutions. The promotion of empowerment and competences aims to encourage learners to act towards the conservation of biodiversity and to develop a sense of responsibility that contributes to sustainable development.
4. **Vision orientation – futures literacy:** Future-oriented perspectives encourage learners to think about the long-term implications of biodiversity conservation and preservation. This future-oriented perspective helps them to understand how important their actions today are for the well-being of future generations.

Constructivist teaching and learning for conceptual change approaches

The constructivist perspective on learning emphasises the active role of learners in constructing their own knowledge through meaningful conceptual connections and interactions with others. To facilitate conceptual change and a deeper understanding, educators should provide structured guidance and ask questions that promote critical thinking, comparison of ideas, integration of new knowledge, and application to real-world scenarios. When creating Discovery Trail assignments (incl. questions), educators should always think and ask themselves what they would like students to understand and whether this set of questions that they have

created supports deeper learning and gives enough structural support while allowing students to concentrate on the assignment.

The constructivist perspective on learning highlights the **mind's ability to form connections between different pieces of knowledge** and from there, the learners need to **actively construct one's own knowledge system to achieve more long-lasting results** (Bringuier & Piaget, 1980). This means that learning happens when the learner has a possibility to create new meaningful conceptual networks (schema) or reorganise existing conceptual systems, often in interaction with others (social constructivism, Vygotsky, 1986) and with the help of language that opens new perspectives when describing and understanding one's experien ces, for example in nature (sociocultural constructivism, Maciel et al., 2004). Thus, conceptual change research develops further constructivist perspectives and helps to better understand the structure of conceptual representations in the learner's mind and ways to support meaningful learning – changes in one's conceptual structure. Conceptual change (CC) approach(es) is/are an effective perspective to take into account if one's goal in teaching is to support the understanding of more difficult scientific concepts (e.g. climate change, biodiversity) where only everyday perceptual experiences may not help or may even contradict with the scientific view (Chi, 2009).

Didactic aspects

The conceptual development process takes time and changes do not occur abruptly, but slowly and gradually (Inagaki & Hatano, 2013). **The conceptual learning process of students should be carefully guided** by educators with the goal of supporting the construction of students' own mental representations (Kember, 1997). There are also various specifically conceptual change-oriented constructivism-led methods that support changes in students' understanding (e.g. summarised by Lucariello & Naff, 2013; see also Morris & Chi, 2020). It has been argued that the minimal guidance that is sometimes used with constructivism-led practices (e.g. discovery learning, problem-based learning, experiential learning) does not help novice learners enough and more structured guidance of the learning experience (not to be mixed with teacher-dominated traditional teaching) may have a better effect on supporting changes in conceptual understanding (Kirschner et al., 2006). This means **that the instruction should provide less support for simply searching for the information and more for guidance on how to use the information to understand the concepts better**, i.e. achieve a deeper learning experience and store the information in long-term memory (Kirschner & Hendrick, 2020). This applies also for widely used questioning dialogue-based methods that we may see as supportive per se, but may actually prompt students' thinking processes more or less, depending on the type of questions/assignments used. Inquiry-based learning outside the classroom that offers structural support through a process worksheet and well-planned questions suggested by Kirschner and Hendrick (2020) is a good way to support deeper learning and conceptual change when learning about more difficult natural science concepts (e.g. biodiversity).

Questioning skills in outdoor learning settings using digital tools

Studies have shown that educators (teachers and staff of extracurricular learning centres) tend to use fewer questions that support the deeper processing of information (see Chen et al., 2017; Chin, 2007 for more examples of questions) when guiding the learning process, compared to questions that are focused on supporting only remembering already known pieces of information and searching for information. This has been

shown in classroom settings (e.g. Yip, 2004) and in the outdoor learning environment using digital tools (e.g. Malleus et al., 2023). If digital tools are used outdoors, it is even more challenging for educators to focus on creating meaningful assignments, as there are a variety of factors that need to be considered (Malleus et al., 2023). **Educators need to have a good understanding of the topic (e.g. biodiversity) and they need to know the location where the questions are used to offer students possibilities of observing the surrounding environment.** In addition, forming meaningful worksheets requires a good understanding of the strategies that support deeper information processing and thus more meaningful learning (e.g. inquiry learning, specific question sets). Moreover, educators need to know well the possibilities and limits of the technical tool that they are using (e.g. the Avastusrada platform). All these aspects are taken into account when planning support materials and teacher training related to the Discovery Trail project (see examples of our Greek and Finnish teacher training blueprints).

Questions that support conceptual change

Specific question types that should support meaningful learning and, more specifically, conceptual change processes have been offered by Yip (2004) and distinguished as eliciting prior understanding (e.g. 'Observe the surroundings here in the park of the nature centre. Do you think it is rich in different species or not? Explain.'), **challenging** to compare the prior understanding with new, more advanced solutions (e.g. 'Ponds by this path seem to be pointless muddy pools. But to which creatures could these be convenient habitats?'), **extending** understanding with new knowledge (e.g. 'Create a hypothesis on how the construction of this new building would affect the biodiversity near the school') and supporting the further **application** process (e.g. 'After learning about the principles of biodiversity, how would you design the landscape structure of this area near the school?'). A similar framework (distribution of questions) has been also used when describing questions that educators tend to use on the Avastusrada.ee platform, but there are also other opportunities to form meaningful questions that support a deeper understanding. For example, when using digital tools in outdoor learning environments, questions that support **inquiry-based learning** (e.g. formulating and testing hypotheses) are useful. Meaningful questions should also support the **exploration of the surroundings** (e.g. 'Feel the temperature under different types of trees. Which would survive dry periods better? Which would cool the surroundings better? Which do you prefer and why?'). Questions that are similar to the application category in the Yip (2004) typology are related to **individual problem-solving in everyday life or making science-informed decisions in everyday life**. These questions could also tap into the motivational aspects of students when going along the trails (e.g. 'How is the food that we eat every day related to different aspects of biodiversity? Which decisions can we make in the supermarket that help to preserve overall biodiversity?'). Moreover, **questions that support the metaconceptual awareness of students** (lead to reflection on personal action) or **handle epistemic beliefs** (see Schiefer et al., 2022 for a meta-analytic overview) in the context of science (e.g. limits of science; the origins of knowledge) are also good to use to support deeper meaning-making during learning outside the classroom.

In the Discovery Trail project, we also asked educators participating in the training to formulate (before the training) and evaluate (after the training) tasks and questions they would use or already have used when teaching about biodiversity. The proposed questions were compared to see what changes the training process has possibly supported. It was found that the educators already proposed various categories of questions before the training, meaning that the participants had an overall idea of effective tasks that support deeper learning process, but after the training, their evaluated examples of questions

reflected their understanding of the importance of using the outer area as a part of the question, allowing students to enhance their understanding.

KEY TAKEAWAYS: What should an educator take into account when planning questions to the Discovery trail platform?

Think where in the learning process the trail is located. Do students already know something about the topic? What would you like to achieve with the questions?

Create fewer questions, but in a way that the questions support students' deeper learning experiences.

Use the surroundings as a part of the question. Make assignments that support the observation, comparison, etc. skills of students and fewer tasks that tie their attention to the mobile device.

Also add questions that support the metaconceptual awareness of students. For example, ask them to justify why they think a certain way and if it could also be described differently.

Part II: Basic considerations about the development of Discovery Trails with a focus on biodiversity and ICT learning

The relevance of biodiversity teaching in the context of education for sustainable development (ESD)

Education for sustainable development (ESD) aims to involve people in various activities to independently acquire knowledge, skills, attitudes, and behaviour. The aim is to create a basis that enables people to make responsible and scientifically informed decisions. Biodiversity is an important factor for sustainable development. Biodiversity literacy refers to the understanding of biodiversity and its importance for the environment and human society. It is essential that people understand the importance of biodiversity to recognise their role in the sustainability of biodiversity and to be able to develop perspectives for conservation in a regional and global context.

General objectives for the development of 'Discovery Trails' with regard to biodiversity are as follows:

- We want to promote the development of biodiversity literacy. This relates to the acquisition of specialised knowledge, skills, attitudes, and behaviour. The content must have a central reference to local (or global) development issues as well as long-term relevance, be interdisciplinary (i.e. it must incorporate differentiated knowledge from various fields), and have the potential for action (de Haan, 2002, p. 16f.). In relation to ESD, the acquisition of competences refers primarily to transversal, multifunctional, and cross-contextual skills and abilities that enable participation in active co-creation (Rieckmann & Schank, 2016; Wals, 2015; Wals & Lenglet, 2016 Künzli 2006, David, 2007, de Haan et al., 2008).
- The international discourse focuses on the acquisition of competences. These can be defined as follows: '*Competences are certain qualities that are required to be able to act and organise oneself in various complex contexts and situations. They comprise cognitive, affective, volitional, and motivational elements and are therefore an interplay of knowledge, skills and abilities, motivation, and affective dispositions'.* These competences cannot be directly taught; learners must develop them through a long-lasting learning process. They are acquired based on repeated experience and reflection in the process of action (through repeated practice in different contexts and situations) (Weinert 2001). Knowledge and dispositions are not opposites, but merely different ways of characterising what can be learned.
- At the same time, we also want to point out and discuss the limits of science, because science is constantly changing and never offers a universal truth or an objective

representation of the world. Therefore, not only a profound understanding of the concepts of biodiversity and biodiversity literacy is needed, but also a discourse that values the dynamic aspects of development characterised by personal cognitive and moral aspects – such as the psychological, social, and emotional development of a human being. Ethical, emotional, and aesthetic aspects that reflect the relationship between humans, nature, and the economy are also referred to as 'social science issues' (SSI; Zeidler, 2014). This is a theory that combines knowledge and values.

The measures of the Discovery Trail project are therefore not only aimed at promoting an understanding of biodiversity, but above all at developing skills, attitudes, and behaviours that contribute to personal development opportunities. Raising awareness of the natural environment is therefore intended to raise awareness of the need to promote biodiversity in various areas.

Biodiversity a complex system

The DISCOVERY TRAIL project generally aims to increase understanding of biodiversity in a complex context. It is important that people understand how important biodiversity is for the survival of plants, animals, and humans. People influence developments in the field of biodiversity in many ways through their behaviour. We therefore endeavour to achieve a certain familiarity with scientific concepts and ways of thinking and working in our project activities, as this is an essential basis for understanding the concept of biodiversity.

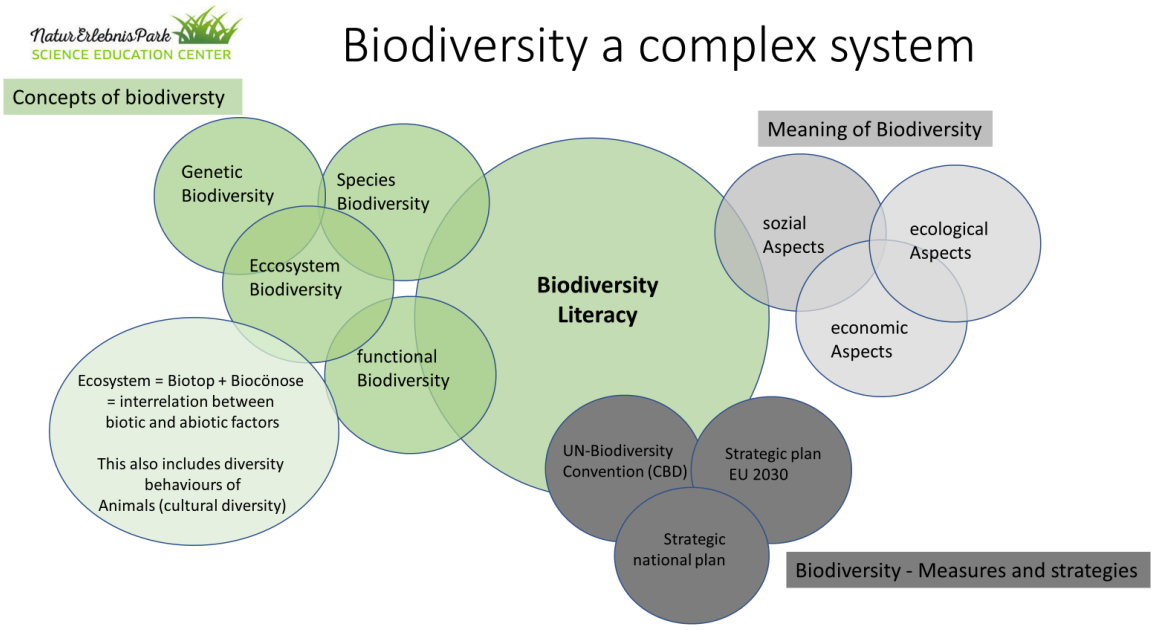


Figure 1: Overview of biodiversity

Didactic measures relate to the scientific concepts of teaching and learning and primarily concern theoretical models and practical implementation. Scientific aspects relate both to the

objectives of the content orientation and to the specific methodological implementation. The complex structure of biodiversity is not easy to understand.

From a scientific point of view, the following reasons can be given for this:

- The concepts of biodiversity are quite abstract and can therefore be interpreted in different ways (van Weelie & Wals, 2002).
  Science is in a constant state of development. The understanding of the dynamics of ecosystems is not yet fully developed and is constantly evolving.
- Biodiversity changes from place to place and from time to time. Evidence suggests that the change in biodiversity is multidimensional and often depends on the specific data that needs to be studied (Chase et al., 2018).
  Various scientific disciplines are involved in biodiversity research. These include chemistry, biology, engineering, law, communication, economics, and social sciences.
- Biodiversity has a multidimensional character. A variety of cultural and socio-economic perspectives also have an impact on biodiversity. Our perception of nature is characterised by our own experiences, cultural norms, and values. The general understanding of biodiversity is therefore based less on scientific knowledge and more on experiences of everyday practice in dealing with nature and on emotional relationships to the environment.

The following aspects can be derived from this for an understanding of biodiversity:

- It is difficult to bring essential knowledge components for the understanding of biodiversity into a logical, ‘coherent’ argument (Gayford, 2000; Menzel & Bögeholz, 2008).
- Not all three levels of biodiversity (the concepts of habitat diversity, species diversity, and genetic diversity) are understood equally; the focus is usually on the level of species diversity.
- Furthermore, the causes and consequences of biodiversity loss encompass complex ethical, economic, and social issues, while learners’ awareness may only associate the problem with ecological issues.
- As biodiversity loss is a global problem, which is usually illustrated by ‘biodiversity hotspots’, the problem is reduced to specific local areas. This ignores the fact that there are interactions at different levels (e.g. regional and global) that also have an impact on biodiversity.

Concepts and definition of biodiversity

The diversity of life is the diversity of living systems and represents the basis of all life on our planet. It encompasses several levels of biological systems and ranges from the level of

genes to the level of populations and species to the communities of organisms and the ecosystems to which they belong.

Biodiversity was addressed globally and comprehensively at the UN Conference on Environment and Development in Rio de Janeiro. This resulted in a global agreement on biological diversity (Convention on Biological Diversity/CBD, 1992), which is defined as follows:

'Biological diversity means the variability among living organisms from all sources, including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems' (CBD, 1992).

Species biodiversity: Individual organisms therefore have a common evolutionary history. Biodiversity refers to biological diversity at the most basic level and is the variety and number of different types of individuals of a species in a particular habitat or geographically limited area. Each ecosystem contains a unique collection of species that all interact with each other. Each species adapts to different environmental conditions caused by climatic, local, and evolutionary changes. This process is called adaptation. To date, around 2 million species have been researched, and around 17,000–19,000 new species are added every year. The number of species living on Earth is not known, but current estimates put the figure at 8–12 million.

The concept of biodiversity encompasses all species on Earth, from plants, bacteria, viruses, fungi, algae, bryophytes, pteridophytes, gymnosperms, and angiosperms to all animal species, including unicellular protozoa and mammals. According to the Biological Species Concept (BSC), a species is a basic classification unit and is defined as a group of similar organisms that reproduce among themselves, produce offspring, and have a common phylogenetic tree. The concept of species is also intended to convey, for example, that some organisms have a common evolutionary history and are capable of interbreeding. This means that they are more closely related to other members of the same group (species) than to other organisms (species).

Genetic diversity: Genetic diversity refers to the totality of the different genes that occur both within a species and between species. Genes are the basic units of heredity that determine the characteristics of an individual. Every animal, every plant, and every human being is unique and equipped with a very specific combination of genes. Each individual usually differs slightly in some characteristics from all other members of its species, because each individual (with the exception of twins, clones, etc.) has a unique genotype. The totality of genes possessed by an individual organism is called the genotype.

Genetic information therefore contains 'blueprints' for the structure and functioning of organisms, which determine, for example, the growth forms and size of a species. Over time, each individual reacts differently to the requirements of its habitat and the respective genetic composition is constantly changing. As a rule, large populations exhibit greater genetic diversity than small populations. The larger the population of a particular species, the more likely it is that the individuals will be able to adapt to changing environmental conditions. This is because the smaller the number of species, the less opportunity there is to recombine

genetic information. It is therefore important for the survival of a particular species in a habitat that the population has a minimum size.

Ecosystem biodiversity

The diversity of ecosystems is the totality of different habitats. An ecosystem consists of a community of many different species (biocoenosis) and a specific, localised habitat (biotope). An ecosystem is therefore a network of interactions between all the organisms living in it and the direct abiotic environment. Ecosystems are very complex, multi-layered systems that are subject to constant, dynamic change due to changing biotic and abiotic environmental factors.

Depending on the region, landscape, and the organisms living there, there are a number of different ecosystems such as rivers, forests, or meadows or even small-scale structures such as dead tree trunks, rocks, and puddles of water. An ecosystem is an area on our planet with similar climate zones, landscapes, animals, and plants. Each ecosystem consists of organisms of many different species that live together in a region and are connected through the exchange of energy and nutrients. It is the natural environment in which plants and animals interact and relate to each other. Ecosystems are influenced by biotic factors, such as the plants and animals living there, and abiotic factors, such as the climate and environmental conditions. The term ‘ecosystem’ is used in the broadest sense to describe these interactions between biotic and abiotic factors in an environment, e.g. dead tree trunks, rocks, and puddles of water.

The nature of an ecosystem is determined by the diverse interdependencies and interactions between the factors (‘ecosystem elements’) that make up its structure. These interdependencies and interactions enable the ecosystem to function and shape its function. Biodiversity plays an important role in ecosystems. We cannot live without ecosystems, i.e. without the units of a habitat and the organisms that belong to this habitat. They have an impact on all of our lives. Every member of an ecosystem – every plant, every animal, every fungus, and every microorganism – has certain functions and interacts with other members of the ecosystem. If a member is lost, its function can usually be better compensated for in a biodiverse ecosystem. It is therefore also important to focus on functional relationships or functional biodiversity. The greater the diversity of genes, species, and habitats, the better nature can adapt to changing living conditions.

Benefits and meaning of biodiversity

Biodiversity is an elementary and existential basis of life for present and future generations and is a prerequisite for the healthy and natural development of all living beings. Biodiversity is a human construct that reflects various values. In its social, economic, ecological, and cultural diversity, it influences humanity directly or indirectly in its everyday life in many different ways. However, the importance of biodiversity for everyday life has still not been adequately recognised by people.

There are numerous reasons for preserving biodiversity.

The preservation or loss of biodiversity essentially depends on people and their decisions. Value systems for assessing the importance of biodiversity are based on the values of

individuals, individual institutions, and society as a whole. These values also vary at the local, national, and global level.

For humans, biodiversity is particularly important due to the services it provides (ecosystem services or nature's contributions to people). In principle, the higher the biodiversity, the better the adaptability of ecosystems to changes in environmental conditions and the more stable the ecosystem services provided. They can be divided into the following categories, with numerous possibilities for interaction between them:

- Economic aspects
- Ecological aspects
- Social aspects

Economic aspects

Biodiversity contributes to material prosperity, and humans are completely dependent on the resources and services provided by ecosystems and their diversity. In the area of key provisioning services, biodiversity influences the provision of food (pollination of crops), the regulation of water quality, soil fertility, and pest control. These factors can increase people's adaptability and resilience to environmental changes and reduce the costs of adaptation and damage prevention. Genetic resources in particular form an essential basis for the supply of raw materials (building materials, industrial raw materials) and for the production and development of active medical ingredients (Morton, S. & Hill R., 2015).

Ecological aspects

Another value system comprises regulating ecosystem services that contribute to the essential preservation of life. Functioning ecosystems have a positive impact on biogeochechemical cycles and regulate biochemical cycles, e.g. oxygen, nitrogen, water cycles, etc., without which our populations could not exist. They play an important role in reducing climate change as they have a major impact on the long-term storage of CO_2, maintaining the balance of CO_2 and O_2 (Rawat, 2015). Without functioning ecosystems, the biodegradation of pollutants and waste would not be possible. Other aspects concern the cleaning of air and water and the reduction of the effects of natural risks, such as the prevention of erosion and protection against drought, floods, and avalanches (Diaz et al., 2018).

Social aspects

Numerous ecosystem services have an impact on human well-being and society. These include cultural services such as recreation, education, inspiration, spirituality, aesthetics, and heritage, which can enhance and enrich people's mental and physical well-being, creativity, identity, and sense of belonging. Considering the social aspects of ecosystem services is important to recognise the value of nature to people, but also to avoid potential conflicts, risks, and side effects that may arise from the use or protection of ecosystem services. Aesthetic reasons and moral lines of reasoning are particularly worth emphasising as they are generally well understood: every form of life on Earth is unique and deserves to be respected – regardless of its value to humans. Humans

are part of nature, and the natural world has value for human heritage. The well-being of all future generations is a social responsibility of present generations; therefore the existence of an organism justifies its preservation (Rawat U.S. & Agarwal N.K 2015).

Biodiversity – measures and strategies

Biodiversity policies and strategies are plans or programmes that aim to conserve or enhance biodiversity. Biodiversity strategies can be developed and implemented at different levels, such as global, regional, national, or local. These strategies are primarily developed through participatory processes involving various stakeholders and experts.

Strategies and measures often relate to key problem areas of biodiversity loss. Progressive biodiversity loss is likely to have serious consequences for humanity. The decline in biodiversity has accelerated dramatically in recent decades, mainly due to human activities. The loss of biodiversity and the associated degradation of ecosystems includes the decline in species diversity and accelerated extinction, the loss of genetic diversity, and the impairment of ecosystem functions.

Main causes of biodiversity loss

- Land use change – destruction and fragmentation of habitats
- Environmental pollution
- Climate change
- Invasive species

Land use degradation – habitat destruction and fragmentation

Habitat destruction and fragmentation is one of the biggest threats to biodiversity on our planet, as it leads to isolated populations and minimises the survival of species. There are many causes of habitat destruction, but the main cause is human activity. This activity includes land use changes such as urbanisation, deforestation, agriculture, and irrigation-induced habitat loss. Habitat fragmentation occurs when ecosystems are broken down into smaller, often isolated components. Isolation leads to altered population dynamics and species composition in ecosystems.

Environmental pollution

The destruction of biodiversity through pollution is one of the main causes of biodiversity loss. Pollution can take various forms, such as air pollution, water pollution, soil pollution, light pollution, or noise pollution. Pollution of habitats can affect the health of plants and animals and reduce their ability to survive. Pollution can also affect the food chain by affecting the food supply of animals that feed on contaminated plants.

Climate change

Climate change is also one of the main causes of biodiversity loss. Global warming leads to changes in ecosystems and affects the living conditions of plants and animals. Rising temperatures can cause species to shift their ranges or become extinct if they are unable to adapt quickly enough. Climate change can also affect the food chain by affecting the food supply of animals that feed on contaminated plants.

Higher temperatures can bring more parasites and pests onto the scene, with further unforeseeable consequences for crops and livestock. Whether humans, animals, or plants – with global warming, everyone has to fear pathogens that will establish themselves in regions that have never been affected and would never have been affected without the climate crisis.

Invasive species

The World Biodiversity Council (IPBES) considers invasive species one of the greatest threats to biodiversity in the world. Species in a healthy, natural ecosystem co-evolve and adapt over time to climate, new predators, and competitors. Most populations are genetically variable enough to adapt to gradual changes in their environment. Invasive species change the functionality of ecosystems very quickly and thus displace native plant and animal species. They can therefore cause considerable economic, health, and medical costs (Convention on Biological Diversity (CBD), 2020).

The development of strategies for the protection and conservation of biodiversity

The development of strategies for the protection and conservation of biodiversity takes place at different levels.

National plan

In **Austria**, the Biodiversity Strategy Austria 2030+ was defined by the National Biodiversity Commission and published by the Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology (Biodiversitäts-Strategie Österreich 2030+). The strategy is based on the vision that Austria will be a country of biodiversity by 2050, in which people recognise, value, and use biodiversity without endangering it. The strategy has ten strategic objectives that relate to improving the status and trends of species and habitats, the sustainable use of biodiversity, reducing biodiversity pressures, promoting research and education, strengthening international cooperation, and implementing and evaluating the strategy.

As at 31 December 2019, **Estonia** has 3,883 protected natural sites, spanning 1,611,297 hectares, including nature conservation areas, national parks, and other protected entities. With over 100 years of conservation history, starting with the Vaika Bird Sanctuaries in 1910, Estonia focuses on preserving species and habitats and promoting environmental awareness. The 1994 ratification of the Convention on Biological Diversity, supporting the Nature Conservation Act, aims for a sustainable environment, aligning with the EU's 2030 goal to protect 30% of marine and land areas. Currently, 81% of Estonia's marine and land areas are unprotected, highlighting the urgency for increased conservation efforts to meet EU targets and combat the destruction of nature.

In **Finland**, the process of preparing a new National Biodiversity Strategy and an associated action plan for 2030 is currently underway. In addition to national goals, the strategy considers the objectives of the UN Convention on Biological Diversity and the new EU Biodiversity Strategy. The strategy aims to strengthen biodiversity protection and promote the restoration of degraded ecosystems. Furthermore, methods to measure the actions and their impacts will be developed. The strategy and action plan will be aligned with both international and EU-level objectives. A new Biodiversity Strategy is necessary as the biodiversity of Finland's natural environments continues to decline. The rate of decline is even faster than before, as measured by the number of threatened species. The strategy's goal is to halt biodiversity loss by 2030 and reverse the trend towards recovery by 2035. (Read more: https://ym.fi/en/national-biodiversity-policy). National parks and strict nature reserves form the foundation of the country's nature conservation network. Other areas designated for biodiversity protection include strictly safeguarded wilderness areas, protected old-growth forests, regions under various conservation programmes, and habitats of special significance as outlined in the Forest Act. Altogether, 2.94 million hectares of forests are either protected or subject to restricted use, accounting for 13 per cent of Finland's total forest area. This includes both forest land and low-productivity forest land, such as forested peatlands. Protected forests are comprised of legally protected areas and biodiversity conservation zones within commercial forests. Of the total, 2.46 million hectares are legally protected, with an additional 0.48 million hectares allocated for biodiversity conservation in commercial forests. The total area under strict conservation amounts to 2.27 million hectares, or 10 per cent of the country's forest area—a significant proportion in global terms. Most of the protected forest areas are located in Northern Finland, whereas the proportion in Southern Finland is notably smaller.

(Read more: https://mmm.fi/en/forests/biodiversity-and-protection/protection-of-forests).

In **Greece**, 34.9% of the land is covered by protected areas, which is significantly above the EU value of 26.4%, while 19.8% of marine areas are protected (12.1% at the EU level). There are also 614 species and 89 habitats protected under EU law in the country. These protected areas and species conservation efforts are vital for preserving Greece's biodiversity and natural heritage[1].

The National Strategies for Biodiversity and Forests were issued by the Ministry of the Environment and Energy in the previous decade. The National Biodiversity Strategy (NBS) (MEE 2014) has been institutionalised since 2014 (valid until 2029) and emerged as a national obligation from its participation in the Convention on Biological Diversity (CBD)[2]. The general targets to be achieved, which are also linked to youth and education, are mainly focusing on[3]:

- Increasing knowledge about the assessment of biodiversity status
- Conservation of national natural capital, ecosystem restoration, and landscape diversity
- Prevention and minimisation of the impacts of climate change on biodiversity
- Protection of biodiversity from invasive alien species
- Enhancing international cooperation for biodiversity conservation
- Integration of biodiversity conservation in the value system of societies
- Citizen participation in biodiversity conservation

- Appreciation of ecosystem services and the promotion of the value of Greek biodiversity

In addition, since 2018, the National Forest Strategy (NFS) has also been instituted, not as an obligation, but as influenced by the publication of the European Strategy for Forests in 2013. In these two texts, visions, general objectives, and policy directions are presented for topics that are often common (Papaspyropoulos et al., 2023).

EU Biodiversity strategy

The EU Biodiversity strategy for 2030 – the Biodiversity strategy for 2030 – European Commission (europa.eu) is a comprehensive plan that aims to protect and restore biodiversity in Europe and globally. The strategy sets out a series of commitments and actions to tackle the main drivers of biodiversity loss, such as land and sea use change, overexploitation of biological resources, climate change, pollution, combating invasive alien species, and integrating biodiversity into all policy areas.

International level

At the international level, there is the Convention on Biological Diversity (cbd.int). It is the most important multilateral treaty for the protection of global biodiversity and aims to conserve, utilise, and fairly share biological diversity. This international environmental agreement entered into force for the first time on 29 December 1993. The convention also contains two protocols: the Cartagena Protocol and the Nagoya Protocol. The Cartagena Protocol regulates the transboundary movement of genetically modified organisms, while the Nagoya Protocol formulates a legally binding framework for access to genetic resources and equitable benefit sharing. Regular meetings of all 196 signatory states are held to discuss the status of implementation and to give new impetus to the process.

Key takeaways:

Including biodiversity in ESD not only expands people's knowledge, but can also inspire them to actively participate in shaping a sustainable future. The following aspects need to be considered to emphasise the importance of education for biodiversity in the context of education for sustainable development (ESD):

1. Understanding ecosystem services: Biodiversity is critical to the functioning of ecosystems that provide essential services for human survival, such as clean air, water, and fertile soil. Education about biodiversity helps people to understand these services and realise the need to protect them.
2. Promotion of nature conservation: Learning about the biodiversity of life forms, the complex interrelationships, and their role in ecosystems leads to a better understanding of the importance of nature conservation activities. This can lead to more sustainable behaviour and supporting conservation initiatives.
3. Addressing global challenges: Biodiversity loss is a significant global challenge that is linked to various aspects such as biodiversity loss, climate change, and pollution.

ESD helps people to understand these interrelationships and the importance of biodiversity in reducing these problems. There are various strategies for achieving this at the national, EU, and international level.

4. Fostering sustainable practices: Education that incorporates biodiversity promotes sustainable practices such as responsible consumption, habitat restoration, and the protection of endangered species. This supports the motivation to align one's own behaviours for a more sustainable future.
5. Cultural and ethical values: Education about biodiversity often includes the cultural and ethical dimensions necessary to support biodiversity conservation. The importance of appealing to moral responsibility is therefore emphasised.
6. Interdisciplinary learning: Biodiversity education requires an interdisciplinary approach that combines biology, ecology, geography, and social sciences and communicates a comprehensive global understanding of sustainability.

ESD and biodiversity in the context of outdoor teaching

The main premise of Discovery Trail is creating meaningful technology-supported learning opportunities outdoors. The platform is a great opportunity for educators, as learning in outdoor environments has been acknowledged as one major opportunity for learning about and caring for biodiversity. In general, engaging in activities beyond the classroom is a valuable opportunity for students to link their academic studies with real-life experiences (Resnick, 1987). Students are shaped by their past experiences, and at times, these experiences resurface in current situations through shared actions, leading to them remembering things and drawing connections between different situations (Lidar et al., 2010). Therefore, authentic settings for science education play a crucial role, providing students with the chance to interact with scientific knowledge and tasks that hold significance in their daily lives. Various efforts to enhance meaningful and captivating science education involve incorporating outdoor learning experiences, such as visits to museums or natural sites (Rennie, 2014). Specifically in the field of biology education, outdoor environments are recognised as genuine learning settings, particularly for topics related to biodiversity and the structure and function of ecosystems (Braund & Reiss, 2006).

Substantial evidence supports the notion that engaging in fieldwork and outdoor learning yields higher levels of cognitive achievement when compared to exclusive reliance on classroom instruction (Eaton, 1998; Ghent et al., 2014; Randler et al., 2005; Scott & Boyd, 2016; Lavie Alon & Tal, 2017). In addition, outdoor learning has demonstrated a capacity to enhance students' personal interest and motivation for learning (Drissner et al., 2010; Fägerstam & Blom, 2013; Randler et al., 2005; Stokes & Boyle, 2009), as well as to foster improved environmental attitudes (Ballantyne & Packer, 2002; Carrier et al., 2014; Drissner et al., 2010). It has been argued that as the ecological understanding of scientists develops progressively from observations and fieldwork, science teaching should likewise follow a 'bottom up' approach, giving more emphasis on observing and inquiring about nature instead of a merely conceptual approach (Barker & Slingsby, 1998; Magro et al., 2001). This approach emphasises the importance of observing and exploring nature rather than solely relying on a conceptual framework (Barker & Slingsby, 1998; Magro et al., 2001). Magntorn and Helldén (2007) underscore the significance of outdoor environments in science teaching, framing it as the process of 'reading nature' and advancing ecological

understanding from taxonomy to system ecology. Waite (2007) and Farmer et al. (2007) posit that positive effects may stem from students forming enduring memories through authentic outdoor experiences, facilitating the efficient recall of learned material. Furthermore, it has been suggested that students' personal familiarity with the natural world outdoors enables them to apply informal prior learning, thereby benefiting academic outcomes (Scott & Boyd, 2014).

As biodiversity manifests locally and basically everywhere, opportunities for learning about biodiversity outdoors are abundant. One can make trips to different natural environments, but even in school yards or in parks near schools, it is possible to make observations about biodiversity with one's own senses. In outdoor environments, it is possible to explore all three levels of biodiversity: diversity among individuals, species, and habitats. Activities such as searching for leaves of the same tree species or examining dandelions of different sizes and appearances contribute to exploring genetic diversity. Observing species diversity can involve various senses, such as looking, listening, and smelling. Especially with small children, there may not be a need to precisely identify species; the key is to marvel at them together and notice the diverse living beings that inhabit our immediate surroundings. With older students, on the other hand, one can investigate species diversity by, for instance, counting all different species within a designated plant square in the field or searching for features in the forest that enhance biodiversity, such as decaying wood and particularly valuable natural sites. Habitat diversity, in turn, is easy to observe by visiting various types of natural sites or, for example, by looking for different types of habitats in a regular hiking destination: dry, moist, sunny, and shady.

Despite the educational potential, there is a growing concern regarding the limited incorporation of fieldwork and field trips in schools (Lloyd et al., 2012; Lock, 2010; Uitto & Kärnä, 2014). Nature outings within formal science education are often infrequent and typically serve as mere additions to conventional teaching practices (Lloyd et al., 2012). The organisation of outdoor education faces various challenges, with some linked to school culture and community dynamics (Hovardas, 2016; Scott et al., 2015). However, many of these challenges are rooted in teachers' perceptions. Research indicates that teachers often lack the necessary skills and confidence to utilise outdoor environments for science activities (Bentsen et al., 2010; Scott et al., 2015). Teachers express concerns about losing control (Glackin, 2017) and seek to minimise student risks (Connolly & Haughton, 2015).

One potential way to organise outdoor teaching activities is to use digital tools. Digital platforms provide opportunities for collecting and sharing observations, structuring tasks for the students, and communicating with students and the teachers (Kervinen et al., 2018, Kervinen et al., 2022). Mobile applications that use location data to guide students through a route and give general or location-based tasks have been suggested to have a great potential in outdoor education (van Kraalingen, 2023).

Suggestions for implementation and the relevance of biodiversity in ESD

In educational discussions, biodiversity education emerges as a pivotal educational concern, fostering a profound comprehension of the interconnectedness between nature, living organisms, and their surroundings among learners.
In this section, we will explore different topics related to biodiversity teaching and learning from simple to more complex ones. All these topics, i.e. habitat and species conservation, invasive species, biomimicry, and nature-based solutions (NbS), could potentially fit into your educational activities and pathways, covering numerous thematic areas of the curriculum.

Biodiversity is an important factor for sustainable development and has been identified by UNESCO Member States as a key priority alongside other new and recurring themes. In the dynamic landscape of education for sustainable development (ESD), education for biodiversity thus identifies itself as an essential keystone. Biodiversity is a common resource that links people, communities, and habitats across large spatial and temporal distances.

Integrating biodiversity into educational activities at different levels and creating awareness of the relationships between biodiversity, nature conservation, and sustainable development at a local and global level is therefore crucial. They provide an opportunity to link scientific education with societal issues and create connecting points for all participants in the DISCOVERY TRAIL project to develop a deeper understanding to become informed, critical citizens. The Biodiversity Strategy (2030) identifies the development of such strategies as particularly important for the next generations to bring about transformation.

Other aspects for achieving our project goals also include implementing measures developed as part of the EU Green Deal 2019. These essentially include the implementation of the United Nations 2030 Agenda, which refers to the 17 sustainable development goals.

Linking topics that are related to the curriculum, as well as the integration of interdisciplinary and multi-perspective aspects and cooperation between formal and non-formal educational institutions, proved to be useful. In the Discovery Trail Project, we are therefore promoting the following considerations:

- learning more about sustainability topics from different fields of knowledge
- recognising and understanding personal and foreign perspectives
- applying decision-making processes to complex issues that affect personal, community, and global well-being

In the dynamic landscape of education for sustainable development (ESD), biodiversity emerges as a cornerstone of future sustainability, contributing to the complex web of life on our planet. Its integration into learning environments not only fosters a deeper understanding of ecosystems and biodiversity

patterns, but also cultivates an appreciation for the interconnectedness of all living organisms on Earth.

Thus, integrating biodiversity into education across different levels and creating awareness of the intersections between biodiversity, nature conservation, and sustainable development is critical to developing the next generation of young leaders that can bring about the transformative trajectory needed to accelerate nature protection and reverse the degradation of ecosystems towards a global recovery (Biodiversity Strategy for 2030[1]).

In this context, the 2019 EU Green Deal[2] is an integral part of the EU Commission's strategy to implement the United Nations 2030 Agenda and the 17 sustainable development goals. 'Schools, training institutions and universities are well placed to engage with students, teachers, parents, and the wider community on the changes needed for a successful transition', whereas 'pro-active up- and re-skilling are necessary to reap the benefits of the green transition'. By embracing biodiversity within educational frameworks, teachers and students gain essential knowledge and skills to address pressing sustainability challenges, instilling values of stewardship, ethical responsibility, and a holistic perspective crucial for shaping the future of our planet. Hence, in the next paragraphs, we aim to highlight several key biodiversity topics that we consider pivotal for integration into sustainability education and the schools' national curricula.

Biodiversity monitoring

Biodiversity monitoring and assessment is the process of measuring and evaluating the state and trends of biodiversity over time. This can include monitoring the populations of different species, the distribution and health of habitats, and the functioning of ecosystems. The goal of biodiversity monitoring and assessment is to detect changes in biodiversity, using satellite and in situ data to understand the causes of these changes, and use this information to inform conservation and management decisions (Convention on Biological Diversity, 2020). The monitoring and assessment can be done using different methods such as remote sensing, field surveys, and citizen science (McGarrigle et al., 2019). Biodiversity monitoring and assessment can also include the development of indicators and metrics to measure progress towards biodiversity conservation goals (Secretariat of the Convention on Biological Diversity, 2018). To this end, biodiversity monitoring is crucial for understanding the current state of biodiversity, detecting changes, and assessing the

[1] https://environment.ec.europa.eu/strategy/biodiversity-strategy-2030_en
[2] https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal/protecting-environment-and-oceans-green-deal_en

effectiveness of conservation efforts; thus, it is a continuous process to ensure the conservation of biodiversity in the long term.

Habitat and species conservation, management, and restoration

Habitat conservation and restoration refers to the protection and management of natural environments and the species that depend on them. This can include efforts to protect and restore ecosystems, such as wetlands, forests, and grasslands, as well as specific species and their habitats, such as endangered animals and plants. Conservation and restoration activities can include land acquisition and management, species reintroduction, habitat restoration, and the control of invasive species (Saunders et al., 1991). The goal of these efforts is to maintain biodiversity and ensure the long-term survival of species and their habitats (IUCN, 2016). Habitat conservation and restoration also plays an important role in mitigating the impacts of climate change (IPCC, 2014).

Decreasing the spatial scale of analysis, species conservation and management refers to the protection and preservation of individual species and their populations. This can include efforts to prevent a species from becoming endangered or extinct, as well as efforts to recover and manage populations of species that are already at risk (IUCN, 2016). Conservation and management activities can include population monitoring and research, habitat protection and restoration, captive breeding and reintroduction programs, and the control of threats such as hunting, poaching, and disease (Saunders et al., 1991).

Protected area management: The goal of these efforts is to ensure the survival of species and to maintain biodiversity (MEC, 2005). Conservation and management activities can be implemented by government agencies, non-governmental organisations, and local communities and can be done through various approaches such as captive breeding, translocation, habitat restoration, and regulating hunting (CBD, 2020).

Invasive species management and management of protected areas

Invasive species management refers to the efforts to control or eradicate non-native species that have been introduced to an ecosystem and have negative impacts on native biodiversity, economy, or human health (ISSG, 2018). These species can outcompete native species for resources, disrupt the functioning of the ecosystem, and cause economic damage to agriculture, forestry, and fisheries (Pimentel et al., 2005). The management of invasive species can include a variety of approaches such as physical removal, chemical control, biological control, and the use of management plans to prevent their introduction and spread (Hulme, 2009). The goal of invasive species management is to protect native biodiversity and ecosystems, as well as to mitigate the negative impacts of invasive species on human communities and economies (IPBES, 2019). The management is a continuous process as new invasive species are constantly being introduced, and there is a need for monitoring and early detection to prevent them from becoming established and spreading (CBD, 2020).

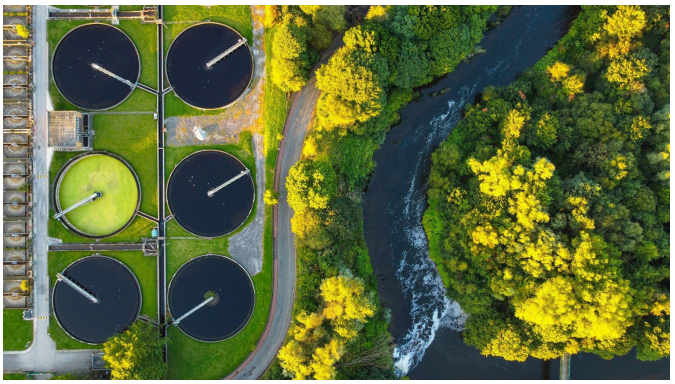
Management of protected areas refers to the planning, establishment, and

administration of protected areas, such as national parks, wilderness areas, and wildlife refuges. These areas are set aside to conserve biodiversity, natural landscapes, and cultural resources, as well as to provide opportunities for outdoor recreation and scientific research. Management of protected areas includes activities such as boundary delimitation, zoning, resource inventory, monitoring, and enforcement of rules and regulations. This management is done by the government agencies, non-governmental organisations, and local communities (IUCN, 2016). The goal of the management of protected areas is to ensure the long-term conservation of biodiversity and natural resources while providing opportunities for public use and enjoyment and balancing competing demands for resources. Protected area management also involves working with local communities and stakeholders to ensure their needs and values are incorporated into management decisions and to build support for conservation (CBD, 2020).

Climate change and biodiversity

Climate change is having a significant impact on biodiversity, as it disrupts the natural cycles and patterns that many species rely on for survival (IPCC, 2014). Rising temperatures, extensive drought periods, and changing precipitation patterns can cause shifts in the ranges of species, making it difficult for them to find suitable habitats (Walther et al., 2002). Climate change can also increase the frequency and severity of extreme weather events, such as droughts, floods, and storms, which can have devastating effects on ecosystems and the species that depend on them (Parmesan & Yohe, 2003). Climate change can also cause changes in the timing of seasonal events, such as the flowering of plants and the migration of animals, which can disrupt the delicate interactions between species (Walther et al., 2002). The impacts of climate change on biodiversity are complex, and in many cases, not yet fully understood, and it is expected to be one of the greatest threats to biodiversity in the twenty-first century (IPBES, 2019).

Biodiversity, ecosystem services, and human livelihoods



Ecosystem services are the benefits that humans derive from ecosystems, such as food, medicine, clean air and water, and climate regulation. Biodiversity plays a crucial role in providing these services, as different species perform different functions within an ecosystem (MEC, 2005). For example, different plants and animals play different roles in pollination, nutrient cycling, and pest control, which are all essential for maintaining the productivity of ecosystems. When we refer to biodiversity loss, we mean that the capacity of ecosystems to provide services is also reduced (IPBES, 2019). As a result, the decline of biodiversity can have direct and indirect impacts on human well-being, including food insecurity, loss of livelihoods, and an increase in the spread of diseases (IPCC, 2014). Therefore, maintaining biodiversity is important for ensuring the long-term provision of

ecosystem services and the sustainable use of natural resources in urban, rural, and coastal environments.

Biodiversity and human livelihoods are also closely linked, as the natural resources provided by biodiversity are essential for the survival and well-being of many communities around the world. Many rural communities, in particular, rely on biodiversity for their livelihoods, such as through hunting, fishing, and farming (IUCN, 2016). However, human activities, such as deforestation, overfishing, and pollution, can have negative impacts on biodiversity, which can, in turn, affect the livelihoods of local communities (CBD, 2020). Additionally, many conservation initiatives also involve working with local communities and stakeholders to ensure that conservation efforts are inclusive and take into account the livelihood needs of local people (IUCN, 2016; Biodiversity Agenda for 2030).

Biodiversity, nature-based solutions (NbS), and biomimicry

Biodiversity and urban sustainable development (USD) are closely linked as biodiversity plays a critical role in maintaining the ecological and social well-being of urban areas (CBD, 2020). Urban areas are home to a significant portion of the world's population, and the sustainable development of these areas is essential for the well-being of both human and natural systems (UN-Habitat, 2020). Biodiversity can contribute to USD by providing ecosystem services such as air and water purification, climate regulation, and pollination. To this end, nature-based solutions (NbS) like urban green spaces such as parks, gardens, street trees, and urban ecological corridors play an important role in providing recreational and psychological benefits to urban residents (Kardan et al., 2015). However, urbanisation and urban development often lead to the loss of biodiversity, and thus it is important to ensure that urban development is planned and implemented in a way that considers the needs of both human and natural systems. This can be done by incorporating biodiversity initiatives into urban planning and design, promoting green infrastructure, and involving local communities in the decision-making process (CBD, 2020).

Biodiversity and biomimicry are also interrelated, as biomimicry is the practice of studying nature and using its designs, systems, and processes to solve human problems. Biomimicry is based on the idea that nature has already solved many of the problems that humans are facing today, such as energy efficiency, water purification, and waste management (Benyus, 1997). By studying the diversity of life forms, scientists, researchers, and engineers can gain inspiration for new technologies and planning and design solutions that mimic the efficiency and adaptability of natural systems through the nine rules of nature (Biomimicry Institute, 2020). Additionally, by understanding the diverse mechanisms that organisms have developed to

survive in different environments, we gain insights into how to design more resilient systems and products that can adapt to changing conditions (Biomimicry Institute, 2020).

Biodiversity and ecological risk assessment

Biodiversity and ecological risk assessment refers to the process of identifying, evaluating, and managing the risks of human activities to biodiversity and ecosystems. This process involves the collection and analysis of data on the exposure, effects, and likelihood of impacts on biodiversity, as well as the identification of options for risk management (Flynn et al., 2019). It is used to assess the potential risks of human activities such as land use changes, productivity and diversity of the ecosystems, pollution types, proximity to disturbance sources or river networks and water sources, the introduction of invasive species, and to identify the potential impacts of these activities on biodiversity and ecosystems (Kontos & Katikas, 2019). The main goal is to identify and prioritise risks to biodiversity and ecosystems and to inform decision-making through the development of risk management plans that aim to minimise negative impacts and promote conservation.

Key takeaways

Incorporating biodiversity into outdoor education – in terms of ESD – can be incredibly enriching for students at different educational levels. Here are some specific aspects and activities you can consider:

1. Biodiversity monitoring (suitable for beginners, primary level)

   - Activities: Simple biodiversity surveys, e.g. counting different plant species, insects, or birds in a local park or school garden.
   - Additional tools: Using simple identification tools and apps such as iNaturalist to help students identify and record species.

2. Habitat and species conservation, management (beginners – advanced, primary and secondary level)

   - Activities: Habitat restoration projects, such as planting native species or creating insect hotels. Advanced students can participate in local conservation efforts or adopt a local habitat to monitor and manage.
   - Additional tools: Guides, habitat conservation manuals, and working with local conservation organisations.

3. Management of invasive species (beginners, primary level)

   - Activities: Identifying and removing invasive plant species from school grounds or local parks. Discussing the impact of invasive species on local ecosystems.
   - Additional Tools: Simple identification guides and tools for safe removal of invasive plants.

4. Biodiversity, ecosystem services, and human livelihoods (advanced, secondary level)

   - Activities: Projects that explore how ecosystems provide services like clean water, air, and pollination. Students can create presentations or reports on how biodiversity supports human life.
   - Additional tools: Research articles, case studies, and interactive simulations.

5. Sustainability Practices: Teaching sustainability through outdoor activities can include lessons on waste management, water conservation, and sustainable agriculture. These practices help students understand how their actions can contribute to a more sustainable future.

   - Activities: Projects that explore how ecosystems provide services like clean water, air, and pollination. Students can create presentations or reports on how biodiversity supports human life.
   - Additional tools: Research articles, case studies, and interactive simulations

ICT and LEARNING

Benefits of ICT learning in sustainability education

The integration of information and communication technology (ICT) into sustainability education has the potential to transform traditional learning paradigms, offering benefits that cater to the needs of the digital age. ICT has democratised access to information, providing educators and learners with unparalleled access to a wealth of global resources. Digital libraries and online databases serve as repositories of cutting-edge research and case studies on sustainable practices from around the world. This means that students can be guided to analyse various sources of information and make informed decisions. This requires learners to sift through vast amounts of information, necessitating critical thinking and analytical skills. When used wisely, ICT supports problem-based learning, encouraging students to engage with real-world sustainability challenges using digital tools (e.g. hybrid learning). This approach not only enhances problem-solving skills, but also prepares students for future careers in a sustainability-conscious job market.

ICT also facilitates global collaboration, enabling learners to connect with peers, educators, and experts around the world. A variety of online meeting platforms provide spaces for collaborative projects, discussions, and exchanging ideas, promoting a global perspective on sustainability challenges. The shift towards digital resources in education contributes to sustainability by reducing the need for physical materials. E-textbooks, online assessments, and cloud-based tools minimise the environmental footprint of educational institutions, aligning operational practices with sustainability principles.

The integration of ICT in sustainability education not only enhances the learning experience, but also plays a crucial role in equipping future generations with the knowledge, skills, and values needed to navigate and shape a sustainable world. In the Discovery Trail project, ICT is used when mixing outdoor learning experiences with technology. If the Discovery Trail platform is used purposefully, it helps to better connect topics learnt at school and seen in the real nature. Moreover, it helps to search for additional information at the same time, if needed, and thus gain more broad perspectives. Even students who are not able to participate in the lesson at the same time could gain the learning experience at an appropriate pace.

To summarise it, we can say that advantages of ICT are:

- enables learning anywhere;
- enables time-distributed learning;
- students can use their personal tool for learning (the teacher does not need to build an arsenal);
- the smart device can be used as a tool for various measurements (temperature, etc.);
- the smart device can guide students to navigate between certain location points;
- allows students to complete the activities independently, but teachers can keep track of the progress of individual students;
- allows students to quickly search for additional information if needed;
- allows giving, for example, video instructions on how to perform an experiment;
- state-of-the-art technologies can be used (e.g. to determine the lens or a description of some natural phenomenon from AI);

- more possibilities to personalise the learning experience by creating tasks that allow students to choose the time and sometimes also the place to carry out the activity;
- teaches digital skills in addition to content;
- supports students with special needs (e.g. by reading the text or enlarging the font size);
- enables modular or hybrid learning (some activities are done in the classroom, some in nature);
- enables continuous and fast content updating.

Hybrid learning

Mixing technology with outdoor learning is a great way to teach children about taking care of the environment. Research shows that children who spend time outside and feel connected to nature are more likely to act in ways that help the planet (Mullenbach, Andrejewski, & Mowen, 2019). Using special computer programs or apps can make learning about the environment more interactive and fun, helping students understand complex ideas about how nature works (Rates, Mulvey, & Feldon, 2016). With mobile phones and tablets, lessons can move outside, making learning more real.

However, it is important to use technology wisely. If not, it can distract students or make them less interested in the nature around them (Hills & Thomas, 2020). Teachers should focus on activities that get children actively exploring and asking questions about the real world, rather than just staring at a screen (Knaving & Björk, 2013). Adding technology to outdoor learning can be tricky. Teachers need to think carefully about how to use tech to make lessons better, not more complicated. They should choose activities that make sense in the context of outside areas and help kids really understand and care about the environment (Pishtari et al., 2019).

In short, using technology in outdoor education needs a careful balance. The goal is to make learning about the environment engaging and meaningful, using tech to enhance the experience, not take away from the natural world. This way, students can learn more about sustainability and how to protect the environment in a fun and effective way.

About Avastusrada

Discovery Trail, known as Avastusrada in Estonian, is a digital tool that enhances outdoor learning. It uses interactive content tailored to various groups – like students of different ages, education levels, and interests – making learning more engaging. This tool is especially useful for environmental education centres and schools.

Explore our trails via Avastusrada online platform that brings together teachers and students across Europe to explore different Biodiversity endeavours

The tool, developed by Tallinn University, allows teachers to create educational trails with tasks linked to specific outdoor locations. It supports the 'bring your own device' (BYOD) policy, meaning students use their own smartphones or tablets to participate. Teachers can access and create trails using a variety of task templates, such as quizzes, open-ended questions, and photo challenges. These trails are open-source, so any educator can modify and reuse them in new locations. The platform also features a real-time tracking option for teachers to monitor students' progress and location during the activity. All responses can be downloaded for later analysis and feedback.

Discovery Trail simplifies the process of combining technology with outdoor learning, offering a dynamic and interactive way for students to explore their environment.

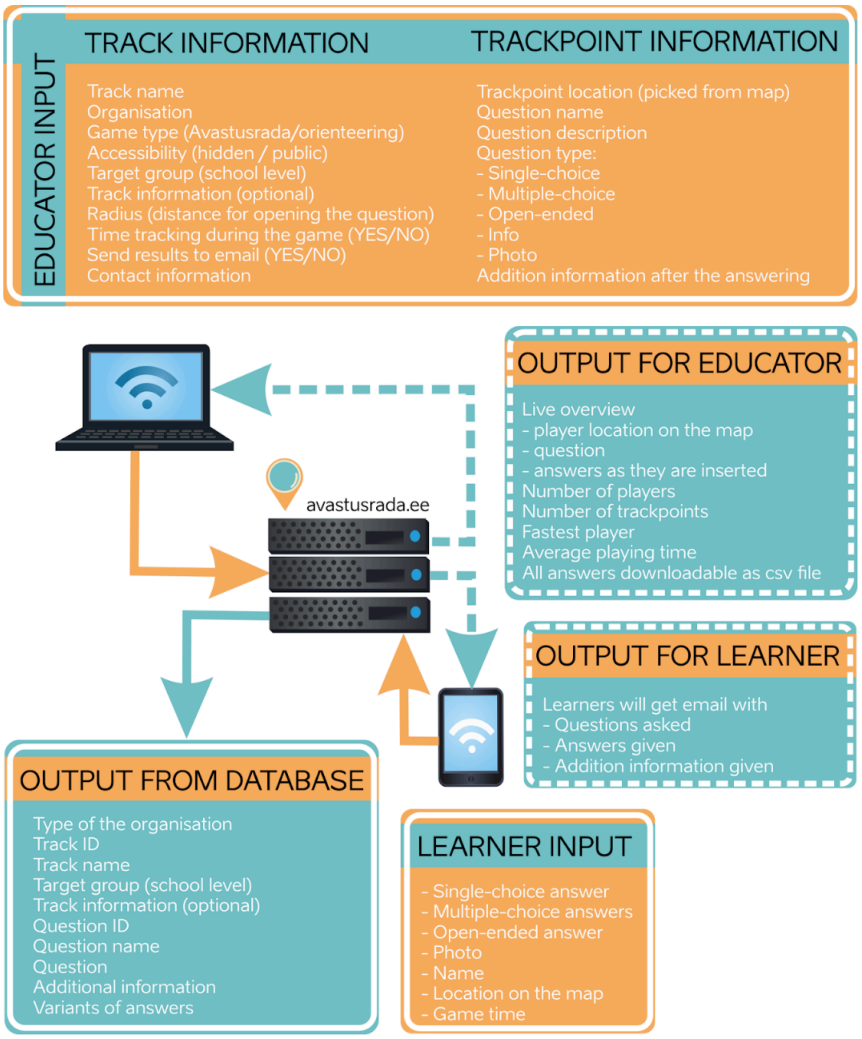


Figure 2. Structure and usage of the Discovery Trail. The flowchart describes the educator's input, output for the educator, the learner's input, output for the learner, and output from the database for current research.

KEY TAKEAWAYS: General recommendations of using and creating trails based on the DT project user experience.

1. In addition to the content of the lesson, the planning of the outdoor education lesson should take into account transport/logistics, security, weather conditions, and the regular curriculum.
2. Pre-test the trail yourself to make sure that the platform provides the necessary functionality (e.g. uploading image files, etc.) seamlessly.
3. Log on to the platform the day before in the classroom to allow time for any technical issues (e.g. lack of a working email address, mobile data capabilities, and limits on the learner's phone) to be identified, resolved, and/or taken into account in the creation of the content of the trail.
4. Support learner participation prior to going on the course with motivation and prior knowledge to support the completion of the tasks on the course.
5. Minimise digital waste.

Part III: Basic considerations for the use of Discovery Trails for the CPD of teachers and educators in non-formal institutions (Blue Print)

Competency-based Pedagogy or PCK (Pedagogical Content Knowledge)

This section focuses on the current initiative and policies for fostering knowledge, practices, and attitudes for education for sustainable development (ESD), reconciling education with principles of human behaviour, biodiversity, and nature overall.

This information can help policy-makers and educators perceive gaps or needs in skill development and Pedagogical Context Knowledge (PCK) that could be addressed through curricula towards competence-based educational activities related to biodiversity. It also provides the theoretical framework that the Discovery Trail project followed for effectively training teachers on different biodiversity topics and pedagogical schemes (i.e. content, pedagogical and contextual knowledge needed).

Sustainable development (SD) is a continuously developing and complex topic, and it is crucial for the future of our Earth that young people have good knowledge of different sustainability issues and challenges. To this end, teaching SD in light of education for sustainable development (ESD) can be perceived as demanding. Past experiences indicate that many teachers have a low self-efficacy for ESD topics and to meet students' learning needs and misconceptions. Therefore, teachers need to plan and adapt their teaching strategies in a way that is closer to the students' reality and real-world examples and settings (Forsler et al., 2023). Hence, sustainability, in its transdisciplinary nature, can contribute comprehensive pedagogical approaches, action-oriented teaching, and competences inside and outside classrooms, and weave together different subjects in a shared narrative with the potential to form active, informed, and responsible citizens of the future. (Fronza & Gras-Velazquez, 2020).

In light of the policy recommendations and the inherent challenges, the Staff Working Document accompanying the European Commission proposal for a Council Recommendation on learning for environmental sustainability (European Commission, 2022) highlights that '*Learning for environmental sustainability requires interdisciplinary approaches, integrating knowledge and skills from different fields. Forest, earth pedagogies and eco-pedagogy can foster learners'*

connection to nature and improve learning outcomes. Participatory, real-life and project-based learning can help build sustainability competences in all phases and stages of education and training.'

In this context, environmental education (EE), climate change education (CCE), and overall, education for sustainable development (ESD) are critical for fostering the skills, attitudes, and behavioural patterns needed to encourage pro-environmental behaviour and awareness in younger generations (Hollweg et al., 2011). In response, the European Commission recently launched the Education for Climate Coalition initiative along with the European Sustainability Competence Framework – GreenComp (Bianchi et al., 2022) and the Digital Education Action Plan and the DigiComp (Vuorikari et al., 2016), which aim to enhance the green and digital competences of teachers and students and foster competence-based educational approaches, curricula and engaging activities or training opportunities. In light of this, UNESCO's 'Decade of Education in Sustainable Development' (DESD) proposes new educational qualities that all national curricula should implement: i) pairing holistic and interdisciplinary approaches; ii) value-driven knowledge with critical thinking; iii) problem-solving; and iv) decision-making (Bhattacharya et al., 2021).

The competency goals and learning outcomes aspired to by high-quality ESD should therefore also be embraced and addressed in biodiversity education. From an ESD perspective, pupils should acquire not only a scientific understanding of biodiversity, but also an understanding of the complex interactions of economy and society that impact biodiversity, and the skills and attitudes needed to participate as citizens in the management of biodiversity for sustainable development on the planet. Moreover, Ulbrich et al. (2010) and Id Badou et al. (2023) highlight that effective teaching practices, especially for biodiversity education, should include a variety of teaching methods (i.e. debate- and challenge-based approaches) and resources, such as field trips, hands-on activities, and multimedia materials, to engage students. The overarching goal is to help them develop a deeper understanding of the importance of biodiversity and the need for its conservation In such an ESD context, biodiversity education would:

- **Appeal widely to all kinds of pupils** [in conjunction with Universal Design for Learning, Rose et al. (2006)];
- Be scientifically sound and **promote understanding of the complexity of biodiversity** issues and management choices;
- Provide **opportunities for students to do research and contribute to knowledge** about biodiversity;
- **Motivate pupils** to act to protect and preserve the diversity of nature;
- **Develop critical thinking and understanding** of why biodiversity is critical for sustainable development;
- **Use ICT effectively** for communication and active participation.

In light of these challenges for teaching biodiversity and focusing on the teachers' perspectives, the most pressing obstacles are linked to teachers' skills, resources,

confidence to teach such topics, and the training opportunities provided. In particular, some major obstacles include the following: i) insufficient knowledge about ESD; ii) absence of appropriate resources, tools, and materials; iii) overall lack of confidence in teaching ESD in a multidisciplinary way, owing to a lack of support and preparative actions, and iv) insufficient engagement on the part of the students. It is therefore especially important that teachers are supported with training in the use of effective and engaging teaching methods and provided with the necessary materials, tools, and pedagogical guidelines (Mulvik et al., 2021).

From a teacher's perspective, according to Barut and Wijaya (2020), lack of pedagogical content knowledge (PCK) among teachers might be a primary factor contributing to ineffective implementation of Environmental Education and inherently, for ESD. One of the knowledge areas needed by teachers is PCK for specific subjects and disciplines, especially when referring to SD. In brief, PCK embodies the integrated comprehension of both subject matter and pedagogies used, shaping an awareness of how subjects or issues are structured, conveyed, and applied in teaching, based on the students' interests, needs, and abilities (Abdullah and Halim, 2010; Pompea and Walker, 2017). Thus, PCK enables teachers to provide teaching situations that help students understand a specific topic, e.g. biodiversity. To illustrate the main components of PCK, the following pillars are identified: i) content knowledge is what is usually taught directly in classes, ii) pedagogical knowledge relates to how the educator would teach a subject and it might include an awareness of student misconceptions, and finally, iii) contextual knowledge, consisting of the broader knowledge, such as knowledge of the scientific method and how it is relevant to the lesson. If the content knowledge is 'what is being taught', pedagogical knowledge is 'how it is being taught', and contextual knowledge is the larger framework (e.g. the scientific method). (Pompea and Walker, 2017).

Addressing the aforementioned challenges and pedagogical concepts, the Discovery Trail project aims to unravel the intricacies of teachers' and students' understanding of complex biodiversity subjects. It is also emerging as a transformative initiative that aligns seamlessly with the goals and challenges for effective and engaging ESD teaching strategies. Through scientifically sound content on biodiversity, critical questions and hypotheses on different biodiversity subjects, and challenge-based approaches, it aspires to foster critical thinking, systems thinking, problem-solving, and creativity, motivating students to explore biodiversity topics and challenges from a unique perspective.

Recognising the pivotal role of ICTs in twenty-first-century educational endeavours and utilising the Avastusrada platform (www.avastusrada.ee/en), the project aims to offer a dynamic and engaging platform that not only imparts information, but also provides students opportunities for research, exploration, and active contribution to biodiversity knowledge, as well as effective communication. From a teacher's perspective: within the project, teachers collaborated with non-formal education specialists (see Sections 'Best practice examples for Discovery Trails' and 'Use of Discovery Trails for CPD of teachers'), providing a unique opportunity to bridge the gap between formal and non-formal learning environments and outdoor experiences.

Key takeaways:

1. Educators often lack resources or training to teach sustainability. PCK helps to bridge this gap by making content relatable and engaging.
2. Platforms like Avastusrada support interactive, participatory learning, enhancing both student engagement and teacher effectiveness.
3. Teachers must connect the content with real-world applications, making lessons relevant to students' everyday lives. This contextual understanding helps students see the importance of biodiversity and sustainability beyond the classroom.
4. Teachers need a solid understanding of the subject matter, such as biodiversity, climate change, and ecosystems, to effectively convey it.

Challenges to the continuous professional development of teachers with the example from the Discovery Trail teacher training process

The continuous professional development of teachers is in focus in many policy documents, where it is described as a continuum together with initial teacher education and school practice (e.g. EU, 2015). In theory, this means that teachers have enough support (incl. financial), possibilities, and time to learn in meaningful ways before and during their career, but in reality, teacher training varies greatly between countries and various challenges are often described by teachers themselves, but also training institutions and policy-makers. For example, studies from different countries have shown that educators feel financial, time management-related, and motivational issues, making it hard to fully participate in training in addition to work (e.g. Drage, 2010; Pasique & Maguate, 2023). Thus, more support is needed for educators to stay up to date with important updates related to their field to be able to teach effectively.

Teaching environmental concepts (e.g. biodiversity) as a general competence related to various other topics in different lessons is important, as it helps to better understand its real meaning and applicability. Teachers need support to be prepared when teaching about biodiversity in their lessons, which is best achieved through continuous professional development. The Discovery Trail project aims to support teachers through its results in various ways. First, it offers an overview of the biodiversity concept and sample virtual nature trails that could be used directly with one's students, allowing one to better understand ways of implementing this topic in various lessons. Second, it supports the competence of using ICT meaningfully to support learning using the Discovery Trail platform. Third, it summarises ways of how to support students' conceptual change effectively with questions and assignments.

Moreover, in the Discovery Trail project, we gained experiences from guiding the teacher training process that help to make better sense of challenges teachers may encounter in learning these topics. For example, feedback from teachers showed that they value the experience of learning together with colleagues from different areas (e.g. natural science teachers and language teachers), but it is sometimes difficult to participate in meaningful conversations when **prior knowledge about biodiversity concepts is so different**. This should be taken into consideration when planning activities related to general competence development with teachers and non-formal education guides. In addition, teachers brought up that it is motivating for them to learn together with

colleagues from different countries, as they see similarities and differences and gain new perspectives. This means that various cooperative learning projects could be a way to overcome motivational issues related to teachers' professional development. On the other hand, we also faced difficulties when asking teachers to join our project, as **it is not so common for all teachers to speak English** and thus being able to join these projects. It was also difficult for some teachers to join a week-long training, as it was **hard to find substitute teachers.** In our project, we experienced that the educators' **skills of using ICT in their learning is really different** and some participants may need extra help from a mentor when starting to use the Discovery Trail platform as a part of their teaching. The Discovery Trail platform also did not work perfectly yet and **teachers who had technical issues felt a decrease in motivation.** It would be best to formulate a network of teachers who have similar training experience and thus a possibility to communicate about various topics.

Introduction of the principles, structure, and content of the teacher training and training of educators in non-formal institutions

The aim of the teacher training (TT) programmes is to expand theories, promote changes in teaching practice, and at the same time contribute to the professionalisation of all participants. The TT programmes as part of the DT project were designed in such a way that various approaches to the development of educational trails were discussed and promoted. The aim was to highlight as many aspects as possible that contribute to a high-quality development of trails. The topics covered included the technical aspects of the Avastusrada platform, the theoretical background of the formulation of specific question types, aspects of biodiversity, and practical approaches to the creation of trails.
The main focus was on emphasising aspects that facilitated an interdisciplinary, participatory development process and aspects that supported the learning process of participants.

Focus on the international participation process

The aim was to promote cooperation at an international and interdisciplinary level. Several meetings were therefore held, both online and in person, to support the exchange of ideas and experiences. Prior to the first pilot group training in Athens, two online meetings were held to give all participants the opportunity to make initial contact with other participants and to get familiar with the DT project and the Avastusrada platform. In addition, the participants worked on theory and analysing 'questions' and collecting ideas of questions that would enable a more in-depth survey of the desired content (biodiversity). The main aims of the meeting in Athens were to explore existing trails together and to develop new trails in a collaborative way.
Before the meeting in Helsinki, there was also an online meeting for all participants, which was aimed at getting to know each other, the DT project, and the Avastusrada platform. In Helsinki, the participants dealt with the testing and further development of discovery trails, which were analysed together in international discourse and with the involvement of people with experience in the development of trails.

Focus on the support of the learning process

When creating high-quality trails, it is important to ask relevant questions that enable a deeper examination of the topic. Suitable questions stimulate thought processes that lead to conceptual change in a theoretical and social discourse based on experience, in the sense of

a constructivist approach. The importance of 'asking questions' was therefore a central aspect of teacher training to initiate learning processes for both teachers and their students.

Structure and content of the teacher trainings in Greece

Description of trail-based CPD sessions

Time: Teacher training in Greece, 6–10 March 2023

Place: Athens, Greece

Preliminary meetings: 22 November 2022, 3–5 p.m. (2–4 p.m. in Austria)

26 January 2023, 3–5 p.m. (2–4 p.m. in Austria)

Participants:

- Project partners and about 6 teachers from each country
- 25 participants in total.
- Both primary and secondary teachers (different backgrounds) and non-formal educators

Description and training objectives:

The learning, teaching, and training (LTT) programme was structured meticulously over a five-day period, aiming to equip educators with essential knowledge and skills for effectively integrating the Discovery Trail (DT) methodology with the use of the Avastusrada platform into teaching biodiversity.

The objectives focused on familiarising teachers with the project, exploring different biodiversity topics, testing the Avastusrada platform, and designing eight trails on different settings (i.e. trails for urban biodiversity, natural parks, and trails inside school) for use in their respective areas. Hands-on and minds-on experiences were emphasised throughout the five-day programme. Participants engaged in technical presentations, test trail creation, and outdoor observation to prepare and experiment with the Avastusrada platform.

Participants explored specific biodiversity topics, actively designed trails that considered specifics of the local area, received feedback, and made adjustments based on their own reflections and feedback. The programme also incorporated reflection sessions, focus group interviews, and collaborative work aimed at creating and refining trails for use in different countries and settings. In particular:

Day 1 (Setting the scene): Designing trails at the Ellinogermaniki Agogi School

Objective: Understanding participants' backgrounds and expectations, setting the foundation of the training, and understanding the DT project goals.

Activities: Overview of the project, group discussions, presentations on biodiversity topics, group work on formulating questions and aiming to create a biodiversity trail at a school environment.

Day 2 (Visiting a natural park): Exploring biodiversity on Parnitha mountain

Objective: This day emphasised practical application by immersing participants in a real-world biodiversity setting in the Parnitha National Park (Attica, Athens). Engaging with the park environment allowed the participants to practically apply their learning in trail design

and receive feedback. One of the main objectives focused on understanding the specifics of local biodiversity and developing questions for a natural park trail (Parnitha mountain).

Activities: Exploring the local biodiversity with a group of biodiversity experts (Trekking Hellas) and formulating questions to be addressed to the students. Designing trails based on the area's specifics and exploring and evaluating trails created by other groups.

Day 3 (Urban biodiversity exploration): National Garden of Athens

Objective: Exploring urban biodiversity and considering the practicalities of conducting trails with students in the city. Focused on applying learning to an urban setting and considering the nuances of testing the trails with students. This day ensured that participants could adapt their knowledge and strategies for varied environments and age groups (upper primary and lower secondary school students).

Activities: Designing urban biodiversity trails, considerations for student trail activities and critical questions, and refining trails based on feedback.

Day 4 (Practice reflection discussions/workshops): Stavros Niarchos Foundation Cultural Center

Objective: This day concentrated on reflection and consolidation, emphasising the importance of evaluating and improving the trails developed. The practice reflection sessions allowed for targeted discussions, tailored to individual country contexts. Reviewing trail creation experiences, discussing effective learning within DT, and country-specific focus groups.

Activities: Summarising trail creation experiences, discussing effective learning, country-specific focus group interviews, planning for the future, and refining the created trails.

Day 5 (Summative discussions):

Objective: Summarising, planning for the future, and testing the created trails with students.

Analysis: This concluding day aimed to consolidate what the participants learned and plan for the next steps, ensuring participants were equipped to implement their acquired knowledge in real teaching environments.

Structure and content of the teacher trainings in Finland

Description of trail-based CPD sessions

Time: Teacher training in Finland, 21–24 May 2024

Place: Helsinki, Finland

Preliminary meeting: 23 April 2024, 4–5 p.m. (3–4 p.m. in Austria)

Participants:

- Project partners and about 6 teachers and non -formal educators from each country (new/old)
- 30–40 participants. In total
- Both primary and secondary teachers and non-formal educators (different backgrounds)

Description and training objectives:

The learning, teaching, and training (LTT) programme was held in Helsinki, Finland. It aimed to provide educators from partner countries with the crucial skills and knowledge necessary for integrating the Avastusrada platform into their teaching processes, focusing on biodiversity education.
This four-day training event equipped educators across Europe to effectively teach biodiversity through practical, hands-on experiences. Using the Avastusrada platform, the training supported the development and application of interactive nature trails. This approach offered a holistic method to environmental education, highlighting practical applications and engagement.

Day 1 (Laying the foundations): Integration of digital tools and biodiversity education
Objective: To provide a comprehensive introduction to the project's history, objectives, and notable achievements so far, establishing a foundational understanding for newcomers. The day also focused on training participants in both the technical and pedagogical aspects of the Avastusrada platform, with an emphasis on designing and enhancing digital nature trails for educational purposes.
Activities: Overview of the project, presentation on biodiversity topics, group work on creating trails near the University of Helsinki and interactive workshops on the biodiversity of ants.
Day 2 (Visiting a forest and a nature park centre): Testing Avastusrada on the field
Objective: To engage participants in a real-world biodiversity setting, allowing them to apply their learning in practical environments. The day involved two key experiences: first, exploring the forest outside the School of Meritori, where participants observed Finnish environmental education in action; and second, visiting the Haltia Nature Park Centre, where they tested an existing trail and designed a new one, refining their skills in trail design while receiving constructive feedback.
Activities: Exploring the local biodiversity with a biodiversity expert in Haltia, the Finnish Nature Centre, testing the trails with students (participation in the forest trip day of Finnish children) and creating new trails based on the morphology of the forest.
Day 3 (Biodiversity exploration): Maretarium and the Unesco world heritage site Verla
Objective: Explore marine biodiversity at the Maretarium and learn about Finland's industrial heritage at the Verla Mill. The focus was on applying environmental learning in diverse settings, such as museums and historic sites, not just in nature. This day demonstrated how to integrate conservation principles across different environments.
Activities: Learning about marine biodiversity through an interactive aquarium tour, learning about the operation of old cardboard factories in Finland through a tour and considering trail activities.
Day 4 (Practice reflection discussions and a summarising discussion): University of Helsinki
Objective: Focused on reflection and consolidation, this day emphasised evaluating and refining the trails developed. Participants engaged in targeted discussions, tailored to their specific country contexts, reviewed their trail creation experiences, and discussed effective learning within DT. The day concluded with summarising insights, planning the next steps, and testing the created trails with students.

Activities: Summarising trail creation experiences, discussing effective learning, country-specific focus group interviews, planning and answering questionnaires.

Key takeaways of teacher training and the training of educators in non-formal institutions:

Both national and international teacher training sessions were/are valuable to both formal and non-formal teachers from different institutions. Based on the participant feedback we have evidence that:

1. It is valuable to have experiences to learn together with colleagues from different areas (e.g. natural science teachers and language teachers), but sometimes it is difficult to participate in meaningful conversations when knowledge about biodiversity concepts might be different. This should be taken into consideration when planning activities related to general competence development with teachers and non-formal education.
2. It is motivating to learn together with colleagues from different countries.
3. ICT skills might vary, so some participants may need extra help when starting to use platforms such as Avastusrada.
4. In the beginning of the DT project, the Avastusrada platform did not work perfectly, which might affect the motivation of participants. It is a good idea to explain to participants that this is a development project.

Part IV: Evaluation and results of the DISCOVERY TRAIL Project

The underlying theoretical approach in the Discovery Trail project is conceptual change (CC) theory. Teaching for conceptual change needs interventions that enable active, effortful, error-prone, and slow learning processes where one can review and re-construct previous concepts. There are various specifically CC-oriented constructivist methods that support changes in learners' understanding (e.g. summarised by Lucariello & Naff, 2013). For example, asking high-quality questions, which are considered supportive per se, can have a positive impact on students' thinking processes, the acquisition of competences, and, ultimately, attitudes towards complex issues.

The application of Discovery Trail as a digital outdoor learning tool can help teachers and non-formal education specialists to guide the conceptual change process of students through well-structured learning experiences in nature. In addition, aspects from the conceptual change theory can be taken into account in teacher trainings when supporting the understanding of educators about biodiversity and effective outdoor learning when using digital tools. Therefore, the aims of the DISCOVERY TRAIL project were (1) supporting the overall understanding about biodiversity and climate change among teachers, non-formal education specialists, and students; (2) guiding the purposeful use of the digital outdoor learning tool Discovery Trail, thinking about possible ways to support the conceptual change process through meaningful assignments and questions; (3) creating a foundation to support forming new networks of different specialists related to environmental education; and (4) to create supportive materials for teachers and non-formal education specialists all over Europe when using the digital outdoor learning tool.

These aims were taken into account when developing discovery trails together with educators participating in the teacher training process, monitoring their experiences, and collecting feedback from various perspectives to make sample trails even more usable and efficient. Well-planned questions can help educators monitor and better support students' overall efficient learning process, but developing sets of trails together also helps educators to learn more about biodiversity, the conceptual change process, and using digital tools purposefully.

Developing discovery trails in a participatory process

The demands on education are constantly changing, which is why it is necessary for the professionalisation of teachers and educational staff in non-formal institutions to be increasingly based on theoretical stringency and empirical evidence.

The interdisciplinary approach of the DISCOVERY TRAIL project aims to foster an understanding of complex environmental issues (e.g. biodiversity) at different levels. This is to be achieved through the development of digital educational trails using the Avastusrada platform. A key focus of the project is to ensure that the participants undergo a certain professionalisation process during the project training, which relates to the professionalisation of both teachers and staff in non-formal institutions.

The participatory action research approach (PAR) is a method in which people are actively involved in researching topics that affect them. The aim is to continuously develop practice through systematic reflection in an iterative process (Altrichter Posch, 2007; Posch & Zehetmeier, 2010). The participatory action research approach, as implemented in this project, aims to expand theories, promote changes in teaching practice, and, at the same time, contribute to the professionalisation of all participants (teachers and staff of non-formal education institutions). It is also based on the underlying hypothesis that the project activities have an impact on all participants.

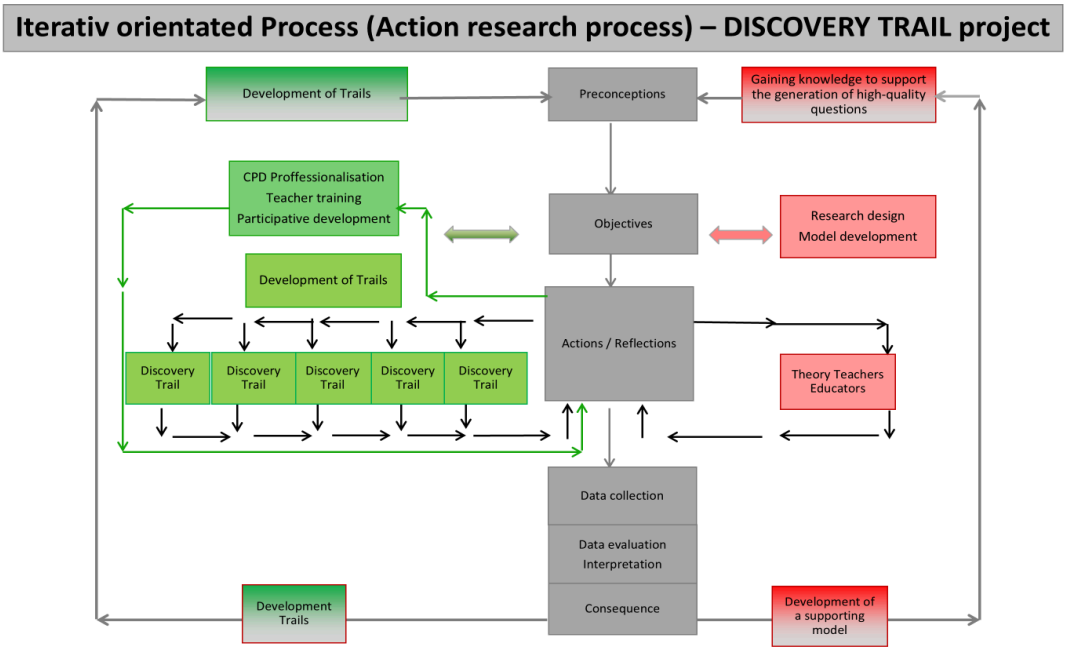
Particular attention in the development process is paid to changing the understanding of content (knowledge about biodiversity), contextual understanding (how can a topic be presented so that connections to everyday life can be found), and the further development of PCK (Pedagogical Content Knowledge), which are developed in an international and interdisciplinary team and thus contribute to the professionalisation of all participants at various levels.

Such an understanding implies that it is not based exclusively on the clarification of a specific situation, but rather that the aim is to allow a newly gained understanding to become effective in practice to improve situations. It thus leads to the question of which new strategies for action can be derived from the project and which newly acquired understanding can be applied to one's own educational practice.

The following aspects for the professionalisation of teachers and educational specialists in non-formal institutions can be derived from the theory for the development of the discovery trails in a participatory process:

- *How science works.* The experience of a research process is part of the professionalisation of the practice of teachers and staff at extracurricular learning centres (Huber, 2006, p. 20).
- *How the acquisition of competency-based thinking takes place.* Key skills such as the ability to summarise and structure knowledge, obtain information, and work independently play a role in this process (Soukup-Altrichter K., Altrichter H., 2012). Specific diagnostic competences such as self-evaluation and the interpretation and implementation of external evaluations also have an influence on these skills (cf. Altrichter & Mayr, 2004, p.).
- *How a general (self-)critical analysis can be carried out.* This requires a certain degree of experience, openness, independence, and structuring ability (Huber, 2006, p. 27).

Approach in the DISCOVERY TRAIL project for the professional development of discovery trails



Graph 3. The iterative participatory action research approach used for the development of discovery trails

Workflow of the development of discovery trails within the DISCOVERY TRAIL project

The participation process for the professionalisation of teachers and staff of non-formal learning centres in the iterative participatory action research process consist of following steps (see also Graph 3)

1. International meeting of the project consortium: getting to know the 'Avastusrada' platform, collecting initial ideas for trails, and defining initial objectives for the development of trails at the national level with teachers and staff of extracurricular learning centres

2. Selection of participants (teachers and staff of non-formal institutions) – 24 participants in total; 6 each at the national level (action and reflections)

- Development of the first trails at the national level
- Piloting of the first trail at the national level
- Evaluation and reflection of the first trail at the national level

3. First international teacher training – common training for teachers and educators of non-formal institutions

- Two international meetings were organised before first teacher training in Athens: WS in hybrid format (online meeting with all participants (international exchange), working on tasks in national groups, additional international online exchange) and preparation for training in Athens: individual tasks distributed for the possible development of Discovery Trails

- First teacher training in Athens (Organisation: Ellinogermaniki AGOGI) – common development of new goals, which can be derived from the previous processes, for the development of further trails. See the structure and content of the teacher training in Greece

4. Further development of the trails at the national level (action and reflection)

- Piloting/testing the developed trails with school classes and individual groups from non-formal institutions
- Evaluation and reflection of the improved trails
- New goals for the development of further trails are defined from the results

5. International meeting of the project consortium – analysis and discussions of the project results on a meta level – analysis of trends in ESD, opportunities for participatory development approaches, the importance of 'learning in the natural environment' – identification of new objectives

6. Second international teacher training in Helsinki (organised by the University of Helsinki) – previous participants share their experiences of the project with other teachers and staff at extracurricular learning centres. See the Appendix 'Structure and content of the teacher training in Helsinki'

- One hybrid format (online meeting with all participants (international exchange), working on tasks in national groups, additional international online exchange) and preparation for training in Athens: individual tasks distributed for possible development of Discovery Trails.
- Second teacher training in Helsinki (Organisation: University of Helsinki) – common development of new goals, which can be derived from the previous processes, for the development of further trails. See the structure and content of the teacher training in Helsinki

Workflow of developing effective questions within the DISCOVERY TRAIL project

A key focus of the project was to gain insights into how the development of high-quality questions can be supported and to identify methods that are suitable for this process. In the project, special attention was paid to providing theoretical aspects (Yip, 2004; Morris & Chi, 2020) and developing a basic understanding of effective questions. Participation process for the development for qualitative useful questions:

1. International meeting of the project consortium: introduction to theories and the development of objectives.
2. International meeting (online teacher training, preliminary meeting): Introduction to the theories and the first collection of qualitative useful questions using creative methods (635) at national level.
3. First international teacher training – joint training for teachers and educators of non-formal institutions. Collection of qualitative questions through group discussions and testing.
4. International meeting of the project consortium: Summary of the results achieved so far and rethinking the objectives.
5. International meeting (online teacher training, preliminary meeting): introduction to the theories and collection of qualitative beneficial questions using brainstorming methods at the international level

6. Second international teacher training – joint training for teachers and educators of non-formal institutions. Discussions and collection of qualitative questions through group discussions.

Evaluation/Results

Different methods and different perspectives were obtained for a more comprehensive understanding of the evaluation of the DT project. Triangulation, which is often used in participatory action research (PAR), was used to collect data. Both a mix of methods and the collection of different perspectives from the persons involved are used as follows.

> In order to manage the user-friendliness and quality of content of the trails, feedback was collected from the core team, teachers and staff of non-formal institutions, as well from students.

The educators (in total 43) in our training groups represented not only different countries (Austria, Estonia, Finland, and Greece), but also a wide diversity of teaching experience (non-formal education and schools), which ensured the inclusion of different practices and expectations in the development process. There were educators with less than 5 years of teaching experience and with more than 6 years (including some with more than 16 years). Professional distribution: non-formal education guides, classroom teachers and subject teachers, including physics, geography, technology, biology, sports, English, and environmental education.

Teachers' views and views of staff of non-formal institutions were collected:

- in a form of a pre-training questionnaire to understand their experience, expectations of the training, and use of the learning pathways (training in Greece);
- during the training and the creation of the pathways, in the course of the experience exchanges (training in Greece and in Finland),
- a questionnaire after the use of the trails to get an overview of the need for upgrading trails (training in Greece and in Finland);

Students' opinions were collected:

- After testing the trails, in a free-form discussion led by teachers or
- After testing the discovery trails, the DT project team conducted interviews with students.

Opinions of core members were collected:

- at the end of the DT project in the form of a questionnaire.

Reflections on the experiences of participants when developing discovery trails in a participatory process

Teachers' perspective

Benefits: Teachers' reflections suggest that the focus on biodiversity in the training was important because it is '*a tricky subject*' that is '*not sufficiently addressed in textbooks', but 'we cannot survive without it'.* Additional material related to topics in the training was highly valued.

Acquiring new ways of teaching that engage students was one of the participants' main expectations before the training, and feedback shows that the training was inspiring: the training added the knowledge that '*a good question raises new questions'.* Working with the test trail made it possible to see how important the formulation of the question is for learners' motivation: the question can motivate or demotivate, '*questions need to be brief, but meaningful*'. Participants also valued the understanding how one needs to take time to observe the surroundings and the created trail should support it with suitable questions: '*make students think, not just observe*'.

The training included designing an outdoor learning trail on the Avastusrada platform and testing it with students. This allowed both users and non-users of similar platforms to become familiar with the platform, which was one of the participants' expectations for the training. Practical implementation of the platform in the creation and use of a test trail will allow this familiarisation.

Bringing together teachers from very different countries provided an opportunity to note the differences (which surprised and enriched) and similarities (which united the group) between school and outdoor learning practices, especially during face-to-face training. The chosen teaching methods in the training supported multicultural learning experiences and offered a variety of possibilities for discussions.

Challenges: Teachers acknowledged that formulating supportive questions for students is not easy. The already known truth is that a question should not be too long or too difficult, nor too simple. Some challenges were also related to the platform's limited functionalities. Teaching biodiversity was sometimes seen as difficult without the suitable background knowledge and possibilities to go outside with students (permissions in some countries, transport and logistics).

In their feedback, the teachers noted that although the language barrier and the very different experiences of the participants with outdoor learning, including digital tools, created some difficulties in the exchange of experiences, it was also enriching and rewarding. When creating lesson content, it must always be borne in mind that the platform is a facilitating tool, thus must not distract the focus from nature. Participants also noted that it would be beneficial to get more one-on-one feedback during the process of creating the trails, but acknowledged that it needs much more time.

In order to make similar training even more effective, teachers suggested planning more time and meetings for the training, including personal consultations with experts to support learning about using the platform, creating the trail, and formulating meaningful questions. At the same time, the opportunity to exchange ideas with other teachers and to test the trails with learners is similarly expected.

Students' perspective

Students' perspective was collected from various trails and age groups (11–19 years) in different countries.

Benefits: It was found that students value the opportunity to learn outdoors as well as playfulness, which digital tools, among other things, can support. Satisfaction with the learning experience is primarily determined by the content, i.e. the questions and tasks.

The students were very engaged and interested in the topic of biodiversity on their 'doorstep'. An awareness and understanding of biodiversity was promoted. The students realised that some things were new to them and that they had discovered a number of topics relating to habitat diversity and biodiversity that they would like to continue studying. The realisation that there are still many new things to discover was an important step in the students' learning process.

When analysing more complex issues, students used their own research results during the DT, additional information materials (texts and internet research), and group discussions. This approach made them feel competent to find solutions on their own in a joint process of discourse. Such an approach not only promotes an understanding of biodiversity, but also important skills such as critical thinking and teamwork.

Students think that discovery trails are a good idea for supporting learning, especially for the new generation.

Challenges: Similarly to teachers, students felt that technical issues distracted from their learning experience. If there are too many questions in the trail, it also demotivates learners, as it feels like a competition.

The students also addressed the following issues:

Internet access is limited to a certain amount of time per day for some students. This is a limitation when carrying out the discovery trails, as well as internet access in the outdoor area. Students have proposed a version with offline access, preloading.

Further suggestions from students:

- an automatic opening of the different activity stations as soon as you are close enough to each station
- an 'overview' of the whole trail to know which stations have already been completed and which are still open
- wish to have their own access to the Avastusrada platform: Students want to be able to go through discovery trails in their free time – with family or friends (repeated practice of the trails in a different context) – for this, students also need to be informed about the use of the Avastusrada platform and how the access works.

Students' reflections also reaffirm the importance of supporting educators in gaining the skills of asking meaningful questions – rather few, but good questions support learners' improved motivation to discover various aspects of biodiversity through engagement with nature using Avastusrada as a supportive tool.

Core team members' perspective

The perspective of the core team members of the project (9 participants) was collected using five open-ended questions.

Benefits: The values emphasised by the core team in the DT project focus on collaboration and diverse perspectives, innovation related to outdoor education, and practical developing experiences. Several participants noted the value of collaboration with international partners, mentioning how '*problem-solving became a shared effort*' and '*cultural differences, but also differences in the field of expertise force team members to formulate their ideas more clearly and add new perspectives'.* This allowed for learning from others' expertise, promoting creativity, and enhancing problem-solving, thus '*being enriching*'. The hands-on nature of the project and working in authentic natural environments were commonly appreciated, emphasising the importance of engaging with nature directly for a deeper understanding of biodiversity. The possibility of thinking about teaching biodiversity using a combination of being in nature and digital tools was seen as a very promising field.

Challenges: Overall, the team members valued the experiences, but also highlighted some aspects related to the challenges that mostly revolved around the technological limitations of the DT similarly to educators' and students' perspectives, but also personal time management, which had to be mastered with a long-lasting project and was related to content of the project, ensuring balance between digital tools and the natural learning experience. Technical problems were felt in the beginning of the project before making changes in the Avastusrada platform, including software bugs, functionality problems, and the difficulty of using digital tools in areas with limited internet connectivity. The issue of time management was frequently mentioned, particularly in terms of balancing different responsibilities and keeping up with the demands of an international project with multiple moving parts, but this was seen as something that is *'as always, the biggest challenge'*. Finding a balance between scientific expertise (all the project core members had scientific background) and educational objectives was another challenge mentioned, as it was important not to pay attention to the aspect of not to overburden participants with too much complexity while still maintaining the quality of learning. Some participants recognised the need to invest more time in exploring the long-term impact of the project, particularly its effect on learning and connection with nature.

The perspectives of the core team members of the project reflect shared values and a strong commitment to collaborative development, innovative use of digital tools in education, and the promotion of sustainable environmental learning. Gathered experiences inspired participants to move on with the work to understand better how to support learning in nature using digital tools. This task of designing trails that could lead to real conceptual changes in students' understanding was more complex than anticipated, but it was seen as an '*essential area for continued work'*.

SUMMARY, ABSTRACT, AND PERSPECTIVES

The Discovery Trail (DT) project aims to deepen the understanding of complex environmental issues such as biodiversity by using digital tools to better understand outdoor learning experiences and integrate ESD. Through cooperation with various experts, the overarching goal of the DT project was to support opportunities through which people are empowered to develop their own way of thinking and acting in an ever-changing world and to be able to participate in democratic processes.

The primary innovation in the DT project is therefore not the use of digital tools alone, but rather the way in which learning processes can be supported in a variety of ways to promote high-quality knowledge gain among both teachers and learners. The DT project created a bridge between authentic learning in nature and digital education.

Based on theoretical findings from educational psychology, innovative didactics and PCK (Pedagogical Content Knowledge) are used in the DT project to support the cognitive learning process and the participatory development of the trail.

The promising results therefore provide indications for the consideration of the following aspects:

1. Creating discovery trails as a training of educators – Support PCK (Pedagogical Content Knowledge)

Objectives: The training of the educators included three levels related to the development of quality DT with the following objectives:

- Cognitive learning process level: A joint participatory development process which aimed to achieve a deeper understanding of educational interventions, especially concerning the formulation of high-quality questions in terms of conceptual change. Deeper engagement with such issues is seen as an important topic in the curricula.
- Content level: Teaching the content of the topic while incorporating scientific dimensions to ensure the correctness of the content as well as its importance for the students.
- Context level: Designing trails in a way that it motivates learners to engage more deeply and meaningfully with their own environment.

Activities: During the project, several training courses were organised for educators at the international level (see the summary of activities in Part III). Sample trails (see the Appendix ‘Best practice examples of Discovery Trails) related to the biodiversity topics were developed as a participatory process during the project. These trails represent the educators’ understanding about possible ways of introducing biodiversity topics for students in various ages (mostly 11–15 years of age) and through length of activities (shorter 30-minute trails, but also project day formats).

Results: Reflections from participants showed that they appreciated the opportunity to learn more about creating meaningful questions and tasks as well as about biodiversity, which was seen as an important topic in their curricula. In addition, the Avastusrada platform was generally accepted. Many educators found it useful and expressed interest in creating new

learning pathways for their students in a participatory way. However, they also stated that they were in favour of even more support for the development of high-quality discovery trails, such as a handbook. They therefore very much appreciate the publication of a comprehensive handbook, as proposed in the DT project.

2. Avastusrada as a digital tool to support outdoor learning and ESD for learners

Objectives: The following objectives were set for the implementation of DT for learners:

- Cognitive learning process level: Dealing with complex and global learning issues makes them feel competent if they have some support for doing this. Such an approach promotes not only a deeper understanding of biodiversity, but also important skills such as cognitive engagement with a thematic area, critical thinking, and teamwork.
- Context level: Designing discovery trails in such a way that it motivates learners to engage more deeply and meaningfully with their own environment.
- Content level: Addressing biodiversity issues at both the global and local level helps learners become aware of their own actions and leads also to a better understanding of wider global implications. The way the questions are posed plays an important role in this context.

Activities: During the project, several discovery trails in each country with learners of different ages were created. The trails were piloted and developed further based on the feedback and user experience.

Results: Learners' reflections showed that they valued the possibility to learn through meaningful questions using a youth-friendly digital tool, but also stated opportunities to make the platform even more user friendly.

This type of learning helps learners to recognise the practical applications of their knowledge, making learning more engaging and meaningful. Activities that involve nature or collaborative discursive engagement foster a stronger connection to the natural environment and society, increasing empathy and awareness. Young learners in particular feel more confident in such learning environments (combination of outdoor learning and digital tools). By including cooperation and teamwork in group activities and projects, learners are encouraged to work together. This enables learners to work together to analyse biodiversity issues and develop sustainable solutions.

3. DT and technical issues and possibilities for expansion

The DISCOVERY TRAIL (DT) project achieved promising results and bridged the gap between authentic learning in nature and digital education. In general, the Avastusrada platform was well received. Many teachers found it useful and expressed their interest in creating new educational pathways for their students. So, the use of the Avastusrada platform to create trails in nature and support meaningful observations of one's environment was successful.

In addition, the Avastusrada platform has been significantly improved based on feedback to make it more usable for educators from different countries. Now, it meets the needs of educators and learners. It can be used in six different languages. There are a variety of ways

in which users can gain access to the platform. Educators who have used the Avastusrada platform throughout the project commented that it would be important to be aware that the Avastusrada platform is still under development and that any feedback from users is greatly appreciated by the developers.

Abstract

As a summary of the project, it can be stated that the main issue in future efforts is to utilise digital solutions in a critical and open-minded pedagogical way in real nature. Guided and purposeful cooperation at different levels (between countries, but also educators from different backgrounds) is a beneficial way to create pedagogical tools as a participatory process and offer valuable learning experiences for all the target groups. Avastusrada platform could benefit in the future from more specific guidelines for the users to create education trails that support students' deeper learning, but also the platform itself could be developed further to meet modern needs.

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Appendix

1. User manual of the Discovery Trail platform (Avastusrada)

The manual can be found here.

2. Best practice examples of Discovery Trails

Trails in Greece

Trails in Austria

Trails in Estonia

Trails in Finland

3. Short guide for educators

The guide can be found here.