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"Scientists moving between narratives towards an ecological vision"

L'Astorina, A., Bergami, C., De Lazzari, A., Falchetti, E.

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Scientists moving between narratives towards an ecological vision

(Photo credit: Sarah Gregg)

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Editorial

Scientists moving between narratives towards an ecological vision

The "*Cammino of Feudozzo*" (CaFe) experience

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Abstract. *Starting from reflections on crises in science and society (Benessia and Funtowicz, 2013; Guimaraes Pereira and Funtowicz, 2015; Benessia et al., 2016) and on the role and responsibility of researchers in a context where calls for a greater public engagement in the process of knowledge building have increased (Owen et al., 2012 Davies, 2014), this editorial describes the experience, called "Cammino of Feudozzo" (CaFe), conceived and carried out within the framework of the Italian Long-Term Ecological Research network*

(LTER-Italy). CaFe is strictly connected with the informal and itinerant science communication initiative called "Cammini LTER", a series of trails (Cammini in Italian) followed since 2015 by LTER researchers, of which it maintains the name and the main vision. In particular, the researchers aimed at critically reflecting on whether and how different ways of understanding and describing the natural environment can have a constructive effect on their work and facilitate and reinforce their dialogue with society. We present the theoretical background and themes discussed during CaFe, with the aim of fostering debate among researchers from different disciplines and exploring other forms of description, knowledge, and interpretation of the natural world (e.g., artistic-aesthetic, philosophical, mythical). In this way, we introduce the special issue of Visions for Sustainability "Scientists moving between different narratives towards an ecological vision", which is dedicated to the perspectives proposed by the participants in the CaFe experience.

1. Introduction

In recent decades, it has become increasingly clear that environmental and ecological crises and those affecting society, culture, ethics, policy, and economy are closely related (Lubchenko, 1998; Millennium Ecosystem Assessment, 2005; Benessia et al., 2016). In 2010, the Policy Statement adopted by the 3rd World Congress of United Cities and Local Government (UCLG, 2010) updated the Agenda 21 for Sustainable Development (United Nations, 1992), by adding the *cultural* dimension to the three main pillars (economic growth, social inclusion and environmental balance) already defined by the United Nations (UN), in order to adequately reflect the complexity of current society and its economic, climatic and ecological crises (EEA, 2021a). Culture is considered as what "ultimately shapes what we mean by development and determine how people act in the world". The UN Agenda 2030 for Sustainable Development attempts to further integrate in a balanced manner all the various dimensions within 17 Sustainable Development Goals (SDG), designed to help face the interconnected and systemic crises of society and the environment (EEA, 2021b). The way human societies interact with their environment has consequences not only on ecosystems, but also on socio-cultural systems themselves and on human wellbeing, as well

as that of all other living species. For the purposes of this editorial, we leave aside detailed consideration of the dangers and paradoxes inherent in maintaining an apparently indissoluble link (at least for policy makers!) between sustainability and development and the consequent emphasis on economic growth. Suffice to say that all the crises we face are symptoms of the same problem: our prevalent model of production and consumption, apparently driven by the unique goal of creating a growing economy, independent of nature, which is destabilizing all the ecosystems that sustain life (EEA, 2021 a; EEA, 2021 b; Giampietro, 2021), as demonstrated, for example, by the sixth mass extinction of species and by increasing climate change (IPBES, 2019; IPCC, 2021).

In this context, calls have risen for a cultural shift, open to multi-, inter-, and transdisciplinary[1] approaches to research, and for a greater public engagement by scientists. Researchers are encouraged to go beyond mere knowledge production or the communication of scientific results and to engage in dialogue with a heterogeneity of audiences (Irwin, 2008; Owen et al., 2012; Davies, 2014). The European "Science and/in/with and for society" (SWAFS) Program and the Responsible Research and Innovation (RRI), challenge scientists' modus operandi, asking researchers to do "science with and for society" and to develop a critical "reflexive, anticipatory, responsive and inclusive attitude" considering the potential societal impacts of technoscientific innovation (Owen 2011). Although the new "epistemology of the European identity", defining the relationship between science, society, and policy (Tallacchini, 2012), requires a full integration of all social actors in the co-construction of knowledge for society, researchers still often consider their public engagement as "peripheral activities" (Glerup, Davies and Horst, 2017), without direct value for them (Meijer et al., 2016). Most researchers often feel "under pressure", considering themselves scarcely trained or motivated to engage in dialogue outside their disciplinary scientific community (L'Astorina and Di Fiore, 2017; 2018).

However, efforts to respond to transformations taking place in science, society, environment, and culture and to the new roles attributed to all actors are increasing, and scientists are starting to reflect on their research and communication practices, opening up to different visions and narratives (Wittmayer et al., 2019).

[1] "Transdisciplinarity goes a step further. It lays claim not to the cultivation of the various disciplines (multidisciplinarity) but to an opening up to 'something' (ineffable and indefinable) that intersects and surpasses each specific discipline" (Panikkar, 2018)

In what follows, we aim to present and discuss a recent experience, called "Cammino of Feudozzo" (CaFe), conceived and carried out within the frame of the Italian Long-Term Ecological Research network (LTER-Italy) (Box 1), with the purpose of fostering debate between researchers from different disciplines and to explore other forms of narration, description, knowledge and interpretation of the natural world (e.g. artistic-aesthetic, philosophical, mythical).

BOX 1 - The LTER Networks

The Italian Long Term Ecological Research Network (LTER-Italy) is one of the 26 national networks of the European LTER Network (LTER-Europe), which comprises more than 400 research sites. It is also part of the International LTER Network (ILTER), distributed in 39 countries over five continents. The principal aim of LTER is understanding, analysing and monitoring changes in ecosystem patterns and processes over extended periods of time, typically decades. At LTER sites, approaches and interpretations of on-going ecological processes are developed (Mirtl et al., 2018; Mollenhauer et al., 2018), also with the aim of creating a legacy of well-designed and documented knowledge for future generations.

LTER-Italy network was established in 2006 and currently consists of 79 research sites, organized in 25 parent sites (i.e., made by multiple research sites), managed and coordinated by public research institutions, universities, and environmental agencies. The sites represent the main ecosystem typologies of Italy: they include terrestrial, freshwater, transitional and coastal marine environments, giving the network a marked interdisciplinary brand.

CaFe is strictly connected with the informal and itinerant science communication initiative called "Cammini LTER" (D'Alelio, 2016; Bergami et al., 2018; L'Astorina et al., 2018a; Pugnetti et al., 2019), a series of trails ("Cammini" in Italian) carried out since 2015 by LTER researchers, of which it maintains the name and the main vision (Box 2). In particular, LTER researchers in CaFe aimed at critically reflecting on whether and how different ways of understanding and describing the natural environment can have a constructive effect on their work and facilitate and reinforce their dialogue with society.

BOX 2 - The Cammini initiative

LTER-Italy researchers planned and realized, from 2015 to 2019, the informal science-communication initiative called Cammini (Trails in Italian) LTER (D'Alelio et al., 2016; Bergami et al., 2018; L'Astorina et al., 2018a; Pugnetti et al., 2019). The initial motivation of Cammini LTER was the necessity of raising awareness on ecological issues, making the public more familiar with the different LTER ecosystems and with the LTER vision and aims, and to share the passion that binds the researchers to the objects of their studies. During Cammini, researchers walked, cycled and kayaked along itineraries, which connected two or more LTER sites, creating a physical and visible movement of researchers towards and with citizens, sharing informal events and communication activities, in close relationship and cooperation with the territories crossed, which were quite heterogeneous in size (from big towns to small villages) and audiences (from school children to elderly people, from lay people to territorial managers, such as foresters, ecological and alpine guards, local environmental associations). Thirteen trails were realized in five years and the initiatives realized during the trails covered most of the communication typologies mentioned in the literature (Bergami et al., 2018; L'Astorina et al., 2018b; Pugnetti et al., 2019). Cammini are inspired by an ancient tradition that perceives walking as a privileged way not only to observe the landscape but to access themselves, others and nature from a different perspective (Solnit, 2000), overcoming barriers that we are often unaware of, and reinforcing the connection with the natural environment (Maturana and Varela, 1998; Varela et al., 1991).

In the Cammini, traditional (e.g., press releases, public conferences, tweets and post on the social networks, reports on blogs) and experimental (e.g., sharing of the LTER activities at the sites, with samplings of the different ecosystems' components and microscopy sessions of plankton and benthos) activities were carried out, aiming at highlighting the relevance of LTER in the territories crossed and the role of the institutions involved. Besides more traditional communication initiatives, more participative and inclusive ones were designed and performed, such as citizen science (Criscuolo et al., 2018a, 2018b), Bioblitz (Petriccione, 2018) and the Sea Futuring Tours (L'Astorina et al., 2018c; L'Astorina et al., 2021). In these contexts, communicating ecology becomes an opportunity to build strong relationships with local actors, sharing different perspectives and ideas of the future on the territory or environment, inspired by the post-normal science approach (Funtowicz and Ravetz 1993).

2. Questioning the role of researchers in the society

Despite several attempts to shift from a Public Understanding of Science (PUS) attitude, based on the idea of filling the "deficit" of knowledge in the public as both the problem and the solution to societal conflicts on controversial issues (Nisbet and Scheufele, 2009), towards a wider Public Engagement with Science and Technology (PEST), the dialogue between scientists and the public is still rare, weak, and frequently distrusted by scientists (Bucchi, 2008; L'Astorina, 2021). The researchers' modus operandi is mainly focused on improving public consensus about scientific research and science reliability, rather than on the dialogue and co-construction of knowledge with society (Avveduto et al., 2012). The development of digital technologies, with the diffusion of the interactive web and of social media represented a major factor of challenge for scientists, as well as offering opportunities to explore mutual exchanges.

To explore the motivations and visions that drive Italian researchers in activities addressed to a wide audience, a series of surveys on public communication and engagement of the scientific network of the National Research Council (CNR) of Italy has been conducted, starting from 2008 (L'Astorina, 2011; Valente et al., 2011, L'Astorina et al., 2013). The results have shown a heterogeneous picture of attitudes, ranging from perceptions of duty to necessity, from usefulness to pleasure in engaging with the public. In some responses to the surveys - especially from researchers involved in ecological and environmental studies - a peculiar interest in a local dimension of communication emerged. In this context, where scientists personally interact with small groups of participants in informal settings (e.g. museums, natural environments), the relationship becomes most direct and is perceived as most meaningful. In local initiatives, participants do not only share the results of research but also emotions, such as the passion that motivates them in their work and binds them to the territory they study. However, these activities are very demanding in terms of time and resources and, especially in the Italian context, they still have low importance in the evaluation of the scientific activity of researchers, also because measuring their complex outcomes and impact is difficult (Jensen, 2014).

In the last 10 years, the opportunities for the scientific network to collaborate with different actors have multiplied and growing examples of participatory research experiences in which scientists work alongside non-scientists in the resolution of concrete problems are being promoted worldwide, changing the cultural attitude of all participants (Giatti, 2019; Kjellström and Mitchell, 2019).

Within this broad context, ecology (the branch of science which studies the interrelationships of organisms and their environments, in the complex interplay of functions and processes, information cycling, cooperative and competitive dynamics) must play a crucial role in a world of rapid change, characterized by socio-ecological conflicts, mainly generated by the prevalent economic model (Benessia and Funtowicz, 2013; EAA, 2021 a and b). Research in ecology has recently shifted towards a socio-ecological approach, where not only environmental but also social and cultural dimensions are considered (Haberl et al., 2006). Researchers in ecology are challenged to act as complex - multidimensional and multi-, inter- and transdisciplinary - professionals in the way they observe and study nature and the environment and to help establish a sustainable and responsible relation with the environment, also through engaging in dialogues with society.

Indeed, ecology is increasingly asserting itself as a way of thinking and being, not only as a scientific approach to describe the environment: "ecological living" is associated with values, ideas, habits, cares, activities, interests, green visions, as well as alternative ways of consuming and/or managing natural resources. Ecological vision is also identifiable in different knowledge practices and forms of culture. In order to embrace this vision and to disentangle complex and wicked global socio-ecological challenges, interdisciplinary research and collaboration are essential (Kelly et al., 2019).

The Cammini LTER initiative (D'Alelio et al., 2016; Bergami et al., 2018; L'Astorina et al., 2018a; Pugnetti et al., 2019) originated from questioning about the ecological researchers' roles and responsibilities (L'Astorina and Di Fiore, 2018; L'Astorina et al. 2018a, 2018b), and therefore implicitly also about their training. This is generally centered only on the construction of specific disciplinary, technical, procedural, and even managerial competencies, not including transversal and soft skills or the exploration of alternative narratives and languages. Moving along alternative pathways is now a recognized research method, allowing participants to make connections between ideas and context, then translated in the ways language is used (Springgay and Truman, 2019). In Cammini LTER we used walking as a process of research, engaging thinking and doing together in an active interpretation of the world (Gray and Colucci Gray, 2018). The aim is to address especially the difficulties for researchers in engaging in social dialogue and sharing goals and significant knowledge with lay people.

Aware of the need for a cultural change, which could lead to involving both scientists and citizens in the care and responsibility for the territory where they live and work (L'Astorina et al., 2018a), some researchers involved in Cammini,

while trying to open up to and explore new ways to strengthen their dialogue with society, left behind, not only symbolically, the comfort zone they were used to (e.g. the desks, the laboratories, the mental schemes, the thematic congresses). This allowed them to experiment informal and unmediated modes of communication (**Table 1**), activating empathy with the people and places and overcoming the sense of separation and distance that often characterizes the relationships between science and society (L'Astorina et al., 2018a; Pugnetti, 2020).

The concept and practice of Cammini LTER, together with the different motivations of scientists participating in the initiative, have been explored and described in a previous issue of this journal (L'Astorina et al, 2018a). The aim of this special issue "Scientists moving between different narratives towards an ecological vision", dedicated to the perspectives proposed by the participants in the CaFe experience, is not only to provide a documentation of the experience, but also to offer a model of methodological experimentation, crossing defined and safe boundaries and exploring perspectives that expand the visions, objectives and practices of scientific research, through dialogues across different perspectives and understandings of the world. The issue presents the set of experiences, comprising workshops, talks, practical sessions and theatre performances, realized during the CaFe.

CaFe was initially conceived during informal discussions and brainstorming among researchers working in LTER and in other socio-ecological contexts, as an expression of a personal need of self-driven professional learning, which could allow exploration of the dimensions of their action and of their world interpretation, and of their willingness to open their minds to other narratives and languages. In particular, it is the outcome of the crossroads of paths travelled in different contexts by the authors of the present paper, each having a different background and being motivated by different questions (Falchetti and Utzeri, 2013; Pugnetti, 2020; Guida and Falchetti, 2021; L'Astorina et al., 2021). They came together in Vicenza, in an informal meeting during the 23rd Congress of the Italian Association of Naturalistic Museums, where the experience of Cammini LTER was presented in a plenary lecture (Pugnetti et al., 2019). CaFe was elaborated and planned involving players with different disciplinary and artistic fields and interests (**Table 1**) with the aim of exploring relationships with Nature in an inter- and transdisciplinary vision. Participants were invited to go beyond their own disciplinary boundaries and languages, and to explore a broader idea of Nature that includes philosophical, ethical, emotional and spiritual, as well as scientific, dimensions (Esbjörn-Hargens and Zimmermann, 2009; Dhiman and Marques, 2016; Wamsler and Brink, 2018; Konig et al., 2021).

3. The place and the participants

The CaFe initiative owes its name to the Cammini LTER (see Box 2), which we wished to recall in order to emphasize the continuity between these experiences, and from the place where it took place, the "Foresta Demaniale Feudozzo e Azienda Sperimentale La Torre" (Castel di Sangro, AQ, Italy), managed by the local department of Carabinieri per la Biodiversità. The location was ideal for our purposes: a natural, inspiring, "pure", quiet, environment, able to host an experience aiming at triggering or recalling natural suggestions and fascinations.

CaFe was held in September 2019 and lasted five days. It was organized by researchers from different disciplinary and artistic areas (Table 1), who proposed experiences and knowledge pathways for activating new interests, attitudes, openings, and relationships within the group involved and with the surrounding natural environment, thus opening to reflections on new ways of doing and communicating ecological research.

The Public Forest "Feudozzo" (**Figure 1**) is part of a large woodland complex between the Abruzzo and Molise regions, near the Man and Biosphere (MAB) National Reserve Montedimezzo. The forest, which covers an area of about 360 ha, between 900 and 1300 metres above sea level, consists mainly of Turkey oak (*Quercus cerris*) and beech (*Fagus sylvatica*). The fauna is characterized also by the presence of endangered species such as the Marsican brown bear (*Ursus arctos* subsp. *marsicanus*) and the wolf (*Canis lupus*). The flora is rich in rare, endemic and protected species. The forest forms a single entity with the land and structures of the Centre "La Torre di Feudozzo", which occupies an area of approximately 110 ha, and is well-known for the breeding of rare-breed horses (Salernitana and Persana breeds).

Of the fifteen participants, nine were recruited through a call launched by the LTER-Italy Coordination Committee and Secretariat, among the LTER site managers, extended to co-workers and collaborators, four were researchers working in the LTER-Italy sites with different roles (e.g. national network coordinator, research site manager, collaborators), three were researchers not directly

Figure 1. Foresta Demaniale Feudozzo e Azienda Sperimentale La Torre. (Photo credit: Amelia De Lazzari)

involved in LTER, and two were environmental guides, who also worked at some LTER sites. Six participants were researchers from LTER-Italy representing the organizing group, who selected and planned the activities, together with the practitioners from other disciplinary areas, and took part actively in the experience (**Figure 2**).

Figure 2. The participants in the CaFe engaged in different activities during the five-day experience (Photo credits: Sarah Gregg and Amelia De Lazzari)

Input for workshops, seminars and talks was provided by actors, epistemologists, photographers, scientists from various disciplines (Table 1), who furnished different viewpoints for investigating, interpreting and describing the natural environment.

All the participants explored together the main questions posed, which emerged out of the previous editions of Cammini LTER, through experiential activities held mainly in the field. The questions can be summarized as follow:

- How can researchers integrate scientific perspectives with other forms of description, knowledge, and interpretation of the world, such as artistic-aesthetic, philosophical or mythical?
- What can they learn from different narratives, expressive forms and cultures and how can these contribute to strengthen their relationship with society and Nature?
- How can researchers learn to dialogue with knowledge and perspectives from "non-experts"?
- What is the role of emotional approaches, which are considered by the neurosciences pivotal in building knowledge and responsible relationships with

the natural environment and society (Panksepp, 2004; Panksepp and Biven, 2012)?

Table 1. The main research topics of the researchers who provided input and the activities they conducted.

Researcher	Research topic	Contribution in the Feudozzo experience
Giuseppe Barbiero *University of Valle d'Aosta*	Affective ecology, mindfulness, biophilia, sustainability	Talks: affective ecology and biophilia Workshop: green mindfulness
Sista Bramini *O Thiasos Teatro Natura*	Science, myth and Nature	Workshops on sensorial perception of Nature Theatre performance: "*Tempeste - Trilogia della rinascita*"
Alice Benessia *Pianpicollo Selvatico, Center for Research in the Arts and the Sciences*	Physics, epistemology, visual arts	Talk: reflections on the quality of research Photography workshop
Bruno D'Amicis	Wildlife photography	Talk and practical session: different perspectives on ecology and how to use photography as a tool for discovery and education
Roberta Latini *Abruzzo National Park, Scientific Service*	Zoology	Sensory theatrical experience: "Io lupo: the wolf tells its own story"
Alessandra Isidoro *Abruzzo Mindfulness*	Sociology, mindfulness, hatha yoga	Mindfulness workshop: reflections on sensorial perception of Nature
Francesca Guida *ECCOM - European Center for Cultural Organization and Management*	Sociology of cultural processes, cultural study-community artistic practice, the role of cultural diversity in modern society	Facilitator and evaluator

The exploration of these questions didn't take place by walking from one LTER-Italy site to another, as in the previous Cammini LTER, but through a different kind of movement, an inner one, guided by unique experiences, alternated with moments for reflecting and debating all together on the proposed themes. The dialogue between researchers from different disciplines and cultural backgrounds, in a suggestive and intimate location, helped the participants to arouse new ideas, feelings and attitudes, accompanying them in a path of self-directed learning about their way of doing and communicating science.

Participants alternated activities in the field conducted as workshops with input lectures on the different topics. During the evening, moments for reflecting and debating all together on the daily experiences were organized and facilitated (Falchetti and Guida, 2021), each participant being asked to share impressions and emotions through a notebook and by writing on post-it notes, then collected in cumulative posters (**Figure 3**).

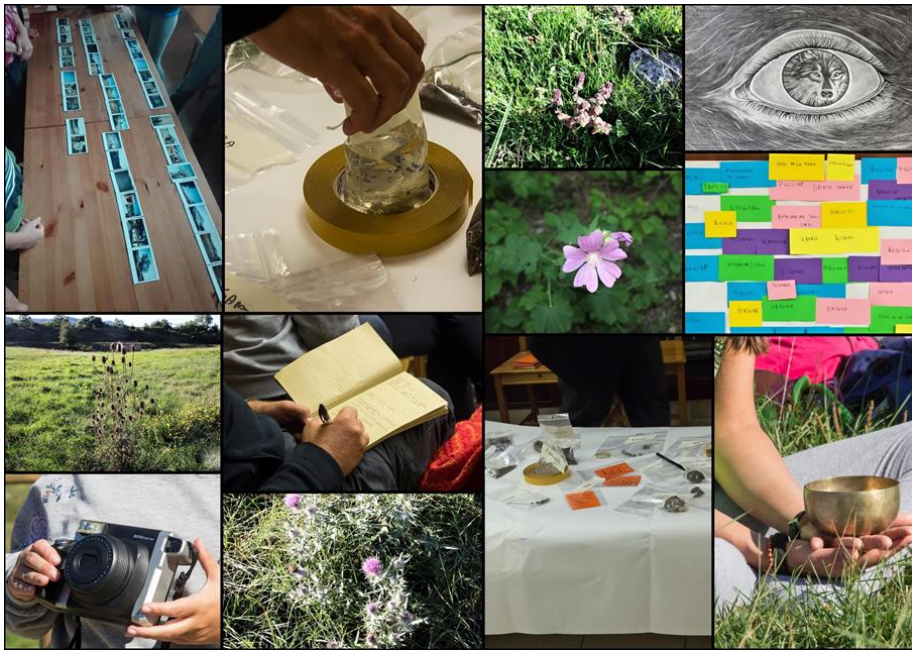

Figure 3. Objects used during the activities and natural elements of the CaFe setting (Photo credits: Sarah Gregg and Amelia De Lazzari)

The activities during the five-days experience were documented by a photographer and by an artist. Most of the experiences are fully described in other papers from this issue (Barbiero, 2021; Benessia, 2021; Bramini, 2021; D'Amicis, 2021).

4. The CaFe concept

During CaFe, we launched a reflection about specialisation, fragmentation of knowledge fields and difficulties in communicating across their boundaries. According to Kuhn (1962), different disciplines convey different ontologies and these can influence our vision and relationships with society and Nature. Science does indeed offer a powerful narration, but it has revealed its limits and cannot offer by itself answers to the complexity and uncertainty of our times (Waltner-Toews et al., 2020). This is a reason why we decided to choose *narration* and *narrative* as two of the leading concepts of CaFe conversations. The idea was to act as storytellers in a special "Cammino", confronting alternative narrations and their particular languages and questioning if and how to integrate them into our thinking and research methods.

Scholars have widely explored the meaning of *narration* and *narrative*. Pedagogists (Bruner, 2003), biologists-cyberneticists (Bateson and Bateson, 2004), neuroscientists (Damasio, 2012), and anthropologists (Clifford, 1997), have described *narration* as a way of thinking, a process whereby brain translates physical experiences and mental activity, a tool for interpretation and communication, a representation of reality in language. Human cultures develop as they are shaped through narrations, which both become and define cognitive and perceptive cultural paradigms, with greater or lesser awareness of the limits and potentialities of a given and other narrations.

Here we follow the definition of narrative proposed by Giampietro (2021): an epistemic device used by human beings to identify and describe relevant causal relations over events, which is necessarily based on a given point of view of the external world. To describe complex observed systems, scientists apply a finite set of attributes, selected on the basis of a prevalent narrative. In this sense, narratives can address complexity because they are not about objective reality, but are statements of what is significant (Allen and Giampietro, 2006).

Another key concept for CaFe was *Nature*. During the workshops our visions and descriptions of Nature were explored and discussed to discover ways in which an ecological vision and natural essence can coexist. What is our personal relation with and experience of Nature? How do we approach our studies

on the natural environment? What are our interests and attitudes towards it? During his seminars on Affective Ecology, Giuseppe Barbiero (2021) highlighted some limits of traditional ecology and stimulated a lively debate on the opportunities offered by other ecological models which include affective and emotional elements, practices and relationships of care, able to reconstruct or recreate connections and bonds - old and new - with Nature. The mindfulness practices experienced by the participants awakened an unexpected sense of affiliation and trust, affective attitudes towards Nature.

As a way of provoking collective reflection, Alice Benessia (2021) proposed a historical account of how science and technology have been defined, legitimized and demarcated over the course of the past three centuries, from the early stages of scientific and industrial revolution to the contemporary age. She considered a variety of figures ranging from scientists from different disciplines to philosophers, sociologists, public officials and entrepreneurs, showing the evolution of the narrative of science and technology over time, and so leading to an intense discussion of the present condition of researchers.

5. The artistic experience of CaFe

Art and artistic research were also central in the CaFe program. Art - music, theatre, photography, dance, visual arts - allows experimentation at a multiplicity of descriptive levels and dimensions, but also to explore other expressive forms, such as "sonification", the movement between art and science describing natural phenomena by means of musical notes and scores (Vicinanza, 2004). Participants of CaFe were introduced to the artistic dimension by Sista Bramini @TeatroNatura (2021) through her workshops offering perceptive-motorial experiences, inspiring different perceptual experiences, through theatre gestures and direct contact with natural elements, fostering new "embodied" and emotional knowledge. Her theatre performance "Tempeste - Trilogia della rinascita", where science, myth and Nature interact, opened new cognitive, sensorial horizons and emotional resonances in the participants, totally new to some of them.

The wildlife photographer Bruno D'Amicis (2021) offered different perspectives for ecological research, which introduced natural complexity and challenged descriptive and emotional dimensions. He introduced the transformative and introspective power of photography, where the relationship with Nature generates knowledge, empathy with natural elements and a feeling of belonging. Photographing Nature, according to D'Amicis' vision, is an ethical and personal pathway towards an intimate perspective. The role of *beauty* in the relationship

with Nature, even if not introduced as a specific topic by the researchers, shaped the whole experience in Feudozzo. The natural place played a role in triggering the participants' aesthetic sense and emotions, while the wildlife photographs by D'Amicis revealed the possibility of harmonizing a rigorous research approach with a fascinated observation of Nature. Beauty is generally ignored in scientific research and mainly considered as an aesthetic category in ecological studies. On the contrary, it can be a potent narrative element and direct ways of knowing and affective attitudes towards Nature. In the case of the perception of ecological-sustainable futures, beauty is a value and an intellectually stimulating resource that combines aesthetic artistic significances with the ecological and ethical ones of sustainability. Studying the "environmental aesthetic" leads to recognition of the aesthetic appreciation of the natural environment plays a leading role in human relationships with Nature. From all these perspectives, the artistic-aesthetic experience taking place during CaFe represents a possible experimental model for conceiving a new, richer and more complex ecological research that is inter- and transdisciplinary and also multidimensional.

6. Concluding reflections and perspectives

According to UNESCO (2000) and the World Science Forum (2019), peace, co-operation, democracy, social dialogue and inclusion, justice, and equity are all values and objectives that science should embed. Similarly, Agenda 2030 considers and asks for actions, proposing a new ecological vision which includes peace, justice, equity, equal rights, well-being and quality of life on Earth in its call for the strategy "Changing our world". This invokes a deep cultural change in the usual scientific models, to make it possible to effectively face complex socio-environmental reality (Kelly et al., 2019). However, most scientists remain oriented towards technology and productivity, rather than towards new ways of thinking, new ethics, and social commitments. Only in recent years has post-normal science (Funtowicz and Ravetz, 1993) challenged prevailing models, testifying that the path for changing is difficult, but necessary and possible.

The ecological researcher's path should promote a thinking, attitudinal and behavioural transformation towards sustainability and peace with Nature. This path should address the researcher towards balance and harmony between personal realization and socio-environmental wellbeing. Achieving these goals also depends on the researchers' feelings and not merely on their technical expertise. During "Cammini LTER" LTER researchers started exploring ways to improve their dialogue with society, aiming to overcome the communication gap and introducing people to unfamiliar forms of LTER research, while fostering an

intimate link with Nature. Out of this experience, an internal critical debate began concerning the necessity to explore different forms of sensing and knowing, challenging well-established rules and models, the impulse which led to the CaFe experience.

The visions and lessons learnt during CaFe were various, reflecting the heterogeneity of expertise, interest and expectations of the participants. Some of them are described in the paper by Falchetti and Guida (2021), who analyze in detail the outcomes of the discussion during the experience as well as the answers to a questionnaire the participants were asked to fill-in, in order to collect their feedback after the experience.

In this extraordinary pandemic period, where the relevance of science for society has become evident but also controversial in public debate, the answers of the participants made us appreciate the relevance and the challenge that this experience - using unusual practices and informal settings to promote reflexive and responsible attitudes - can represent for scientists invited to move outside the comfort zone of their institutional workplace. The impressions reported by the participants, the words and the expressions used to describe them, confirmed the initiative as an opportunity - unusual for their scientific paths - where scientists could reflect on their research practices and narratives.

One of the main topics that emerged as a challenging issue concerned the sense of "belonging to a scientific community", despite different areas of specialisation and fragmentation of knowledge fields. Moreover, the necessity to move beyond the common idea of communication as a process of "transmission" of scientific contents from those who are supposed to know (scientists or experts) to those who don't know (the public) emerged. For example, in Sista Bramini's workshop communication was experienced as a process of mutual listening between different forms of knowledge and narratives, revealing the weakness of only referring to one's own perspective when faced with planetary challenges. If considering ecosystems and biodiversity - as well as the responsibility towards them - does not only imply facts and data but also values to be shared among all social actors, then collaboration is necessary among all different players who live in, manage, or study a territory. Within this scenario, communication becomes a necessary precondition to allow relationships between actors to become more intimate and aware and to make all take care of the environment in a constant and effective way (Folke et al., 2011; Jamieson, 2011).

Sharing ecology entails the potential to create an intimate bond with nature and the territory. During CaFe, most participants experienced another type of

knowledge of the places and communities they are studying, based on qualities connected with emotions and with a peculiar kind of perception, which deeply bond us with Nature and can fruitfully coexist with scientific and rational knowledge and words (Harding, 2011; Barbiero, 2011, 2014). Gathering theoretical knowledge together with sensory experiences and approaching Nature from different points of view (scientific, artistic and well-being), which was the main aim of CaFe, led the participants to start integrating in their research an inner dimension, including emotion and affectivity, thereby enriching knowledge building.

An important part of these reflections was dedicated to research practices. Participants focused on how their habit of being "caged in rigid and bureaucratic schemas", including automatisms and repetitiveness in actions, can be an obstacle when they are asked to engage in dialogue with society. Within this context, the necessity to acquire skills in communicative contexts cannot be disconnected from the need to develop a new inner attitude, welcoming plurality and transdisciplinarity in their scientific approach. They also expressed the willingness to continue along this new path, seeking ways of finding and sharing alternative experiences and approaches within daily experiences. Some of them criticized the conditions of research work, characterized by excessive competitiveness, as a limiting factor in the communication among colleagues.

All the participants agreed that, while the traditional formula of Cammini LTER is still a desirable one for the future, the CaFe experience represented a new starting point for reflecting and linking together the different paths explored as well as the valuable knowledge encountered along the way.

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Competing Interests

The authors have declared that no competing interests exist.

The Forest

I am the Forest
wild, ancient and sacred.
I am the origin of the world
in every seed, plant and leaf.
Thousands of shades of green
dominate my infinite inside,
which contaminates
every wrinkle in a time
that here no longer exists.
Only space,
in its infinite dimensions,
resonates in every color.
It is the energy of the Earth
that dominates the labyrinth of shapes
that live within me,
and here, as nowhere else,
words, by magic,
meet
and there are strangers no more.

(*Amelia De Lazzari*)

Position Paper

Implications of Complexity Theory

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1. Introduction

During the last decade, it has become increasingly clear—at least to those who want to see it—that our model of economic development is incompatible with the limits imposed on us by nature. Note that I am not only referring to climate change. Our current path of development is systematically de-stabilizing all ecological systems that collectively provide our life support system. For example, the 2019 IPBES report simply reveals a biodiversity horror story (IPBES, 2019). The continuous increase in population size and the growing expectations for a higher standard of living worldwide have caused us to move from an 'empty world' to a 'full world' (Daly, 1990; Goodland & Daly, 1990). While in the former resource availability per capita was sufficient to prevent us from perceiving the existence of limits to growth, in the latter these limits have become painfully evident. Nonetheless, policymakers pretend these limits can be overcome by business models and technical innovations, thereby resorting to policy legends and socio-technical imaginaries to retain legitimacy (Giampietro & Funtowicz, 2020; Jasanoff & Kim, 2015). Indeed, humans are ever more alienated from nature. The

Oxford Dictionary definition of nature, endorsed by organizations such as the OECD, speaks for itself: "Nature is the phenomena of the physical world collectively, including plants, animals, the landscape, and other features and products of the earth, *as opposed to humans or human creations*". This definition suggests that "*homo economicus"* is not part of nature nor evolved on this planet, as if we were instead rational cyborgs, with the sole goal of creating a growing economy independent of nature. (This may well explain the success of the EU circular economy action plan in which human society supposedly will no longer rely on the exchange of inputs and outputs with the biosphere).

Concurrent to and interrelated with the environmental collapse, we are experiencing a no less important cultural crisis. We are in an ideological cul-de-sac. It has become increasingly intolerable to live in a society in which the economy grows by destroying the environment, the rich become richer and the poor poorer, farmers disappear faster than other endangered species, and the only solution to maintaining a high standard of living is a legalized global "Ponzi scheme" (also known as "quantitative easing" or free printing of money for the rich). The profoundness of the crisis is evident from the fact that, in spite of paying lip service and showing indignation, we are accepting this situation that translates into losing social bonding, within and across societies. If people no longer believe in their ability to change things together, there is little policymakers can do. This loss of social bonding results from the progressive crumbling of our identity as individuals and as society. "The function of this new economy, legal and illegal, is to entertain and distract a population which - though it is busier than ever before - secretly suspects that it is useless" (Gray, 2002, p. 160).

Given these two challenges, the following questions arise. Can we change the current path of development toward a society that strives for caring for each other and the environment, rather than accumulating capital? Is such a transformation possible by relying on the neoliberal recipe of new business models (invisible hand of the market) and technical innovations (human ingenuity)? Can the sustainability and related political crisis be solved solely through the implementation of a series of technological fixes? These questions point to the key role that science should play in solving the sustainability crisis and the profound intoxication of the current debate by the Cartesian dream of prediction and control (Guimarães Pereira & Funtowicz, 2015). The persistent idea that we can solve any complex problem with "optimal solutions" delivered by carefully planned business models and advanced technologies prevents developed societies from considering "something completely different", like a caring economy. At present, it is unthinkable to explore alternative social practices unless the plan of action is

"scientifically proven" and fully "under control" by the current establishment. The system of governance of contemporary society is no longer capable of handling uncertainty. This has led to a logical impasse. On the one hand, we are aware that ruling institutions (national governments and international bodies) have lost control and that our society has become fragile and susceptible to perturbations. On the other hand, we are reluctant to explore alternatives because we fear risking to lose even more control (as well as privileges). We, in the sense of both individuals and society as a whole, are scared of making changes. Given this situation, are scientists helping or making things worse? Can science handle complexity and uncertainty?

2. Narratives in sustainability science

A complex phenomenon is a phenomenon that requires a simultaneous perception and representation of its various relevant aspects using several non-equivalent narratives and dimensions and scales of analysis (Allen & Starr, 1982; Funtowicz & Ravetz, 1997; Giampietro, 2003; Giampietro et al., 2006; Rosen, 1977; Salthe, 1985; Simon, 1962). I define here a narrative as an epistemic device used by human beings to identify and describe relevant causal relations over events. A narrative is necessarily based on a given (particular) point of view of the external world. It provides explanations that are potentially useful for informing action; the extent of usefulness being dependent on the purpose of the chosen narrative. That is, the choice of a narrative is made in a pre-analytical phase, before the modeling and quantification associated with scientific work takes place. A narrative entails the choice of a descriptive domain (the space-time scale and dimension of analysis), but in order to be relevant it has to be useful for an agent having a specific purpose. A narrative permits identifying the set of attributes (what has to be observed) relevant for the representation (the models).

The epistemological predicament of complexity for science entails that any model that generates an exact description of the observed system and provides crisp numbers can only do so because it only describes a finite set of attributes, which the scientist decided to use in the description of the system based on her/his narrative. As eloquently stated by Box (1979), "*All models are wrong. Some are useful*". The usefulness referred to will depend on the quality and the coherence of the choices made in both the pre-analytical and analytical steps of the investigation (Giampietro et al., 2006). In the same spirit, Lakoff (2010) suggests that any framing of a problem entails "hypocognition", especially when the framing is associated with the choice of quantitative variables. In other words, the chosen framing ignores a large set of relevant aspects of the problem at hand.

In **Figure 1**, I illustrate my point with a simple example using different combinations of narrative, storyteller and contextualization. In the first column (on the left), we have a list of four narratives along with the context in which they are proposed. In the second and third columns, we have different story-tellers/users who are expected to endorse and use (one of) the explanations for guiding their action.

NARRATIVE	Story-Teller/User	Story-Teller/User
EXPLANATION 1 → "no oxygen supply in the brain" *Space-time scale*: VERY SMALL *Example*: EMERGENCY ROOM	Virologist	Doctor in the emergency room
EXPLANATION 2 → "affected by COVID 19" *Space-time scale*: SMALL *Example*: MEDICAL TREATMENT	Philosopher	Pharmaceutical Researcher
EXPLANATION 3 → "lack of an adequate vaccination in the population" *Space-time scale*: MEDIUM *Example*: MEETING AT HEALTH MINISTRY	Doctor in the emergency room	Virologist
EXPLANATION 4 → "human must die" *Space-time scale*: VERY LARGE *Example*: SUSTAINABILITY ISSUES	Pharmaceutical Researcher	Philosopher

Figure 1. Non-equivalent narratives about the death of a person showing that narratives are neither true nor false, but useful or useless

If we look at the list of story-tellers/users in the second column, it is evident that none of the corresponding explanations provides any useful insight for guiding their action. On the contrary, if we consider the last column of story-tellers/users, all the chosen narratives provide useful information for their purposes. This shows that scientific explanations based on a pre-analytical choice of a narrative of a phenomenon are neither true nor false, but they may be useful or useless.

The point that the usefulness of a narrative depends on the nature of the concern of the story-teller is further elaborated in **Figure 2**. In this example, rather than providing a list of explanations, I show a list of story-tellers/users of a chosen narrative (in this case, different scientific experts participating in a single conference) and their advice on how to achieve a desirable and fair food policy. Note that, in contrast to the previous one, this example has not been made up,

but rather reflects presentations and discussions in a scientific conference in which I participated.

Figure 2. Contrasting scientific advice of different experts/story-tellers at the SAGUF World Food Conference, Zürich, 9-10 October 1996

The contrasting advice provided by the invited experts refers to three different aspects of food security (national policy, international policy, gender issue). All the advice was given by reputable scientists and supported by convincing evidence. However, if we look at Figure 2, we see that, depending on the problem the expert wants to solve (i.e., the purpose/prioritized concern of the agent), a pertinent advice can be legitimately in contrast with another pertinent advice (e.g., protecting the nutrition of the urban poor versus protecting the income of poor farmers). Hence, the purpose of the food policy (the choice of the problem to be solved) can be associated with the "identity" or cultural context of the story-teller, which determines the priority of the concern to be addressed. In this particular example, all the story-tellers from developed countries suggested policies that stabilize the status-quo (considered desirable), whereas those from developing countries suggested policies that aimed at changing the status-quo (considered undesirable). This example demonstrates that the quality of the process of policymaking cannot be analyzed in scientific terms only.

The contrasting advice reflects the existence of trade-offs over different points of view of sustainability. But how to establish priorities over the concerns of the various social actors? In the first case, the concerns of the urban poor are weighted against the concerns of the rural poor. Protecting the urban poor by keeping food prices low translates into low revenues for farmers, who consequently will not be able to invest in producing more food. Nonetheless, a larger supply of food, if more expensive, will not necessarily help the urban poor.

In the second case, developed societies, by importing food commodities from developing countries, are externalizing environmental stress to ecosystems located in the exporting countries. However, if the rich countries stop importing food commodities they hamper the economic development of the agricultural sector of developing countries that enjoys comparative advantages (lower cost of production). In this case, the concern for the environment (in developed countries) contrasts with the concern for a low level of economic development (in developing countries).

The last example in Figure 2 about social policy is even more striking. While nobody would object to the need to preserve cultural traditions and identity across the globe – given the key role played by women in guaranteeing food security, it is also true that there are specific situations (like the one shown in Figure 2) in which it may be opportune to change the local cultural heritage. Again, in this example it is evident that generalizations and written rules cannot be applied without considering the specific context and the point of view and the emotions of people experiencing the event represented in the scientific analysis. Scientists alone, without interacting with the society within which they are operating, cannot deal with the prioritization of concerns. For this reason, it is essential for scientists to carry out a continuous revision of the "meaning" and "usefulness" of the narratives used to generate their representation in relation to the evolving context. This entails that we have to continuously revise, in an iterative process, what are the concerns to be addressed by society, how to define our affective interactions, and how to identify the social practices that reinforce a caring society. In this process of evolution, we have to be open and flexible when scientific narratives and models are in need of updating.

3. What role for sustainability scientists?

The terms "sustainability science" and "the science of sustainable development" were 'officially' coined in 1999 by the National Research Council (National Research Council, 1999). Many different definitions and views of sustainability science soon followed (see, for example, Fang et al., 2018; Kajikawa, 2008; Miller, 2013; Spangenberg, 2011; Ziegler & Ott, 2011). Perhaps the most ambitious is the following definition of Kates et al. (2001), in an influential paper in *Science* (emphasis in italics is mine):

> "A new field of sustainability science is emerging that seeks to understand the fundamental character of interactions between nature and society. Such an understanding must encompass the interaction of global processes with the ecological and social characteristics of particular places and sectors (..). The regional character of much of what sustainability science is trying to explain means that relevant research will have to integrate the effects of key processes across the full range of scales from local to global (..). It will also require fundamental advances in our ability to address such issues as the behavior of complex self-organizing systems as well as the responses, some irreversible, of the nature-society system to multiple and interacting stresses. *Combining different ways of knowing and learning will permit different social actors to work in concert, even with much uncertainty and limited information*."

Martens (2006) and Spangenberg (2011) point out that science of sustainability concerns a new research paradigm that recognizes uncertainty and exploration (as opposed to prediction) and emphasizes the importance of co-production and co-learning through an extended peer community and stakeholder engagement.

Indeed, as noted, it is particularly important to define not only "what sustainability science is about", but also "who are the social actors in charge to generate this new type of science". A passionate call in the direction of radical change in the conception and definition of sustainability science has been made by the community of Post-Normal Science (PNS) (Funtowicz & Ravetz, 1993; Funtowicz & Ravetz, 1990, 1994). PNS is an alternative approach for the use of science for issues where "facts [are] uncertain, values in dispute, stakes high and decisions urgent". The rationale of PNS is summarized by the iconic graph shown in **Figure 3**, which illustrates that the credibility of the "normal" scientific approach (in the interpretation of Kuhn) becomes increasingly controversial as the level of decision stakes and system uncertainty grows. This graph neatly shows the different roles that scientists should play in different situations.

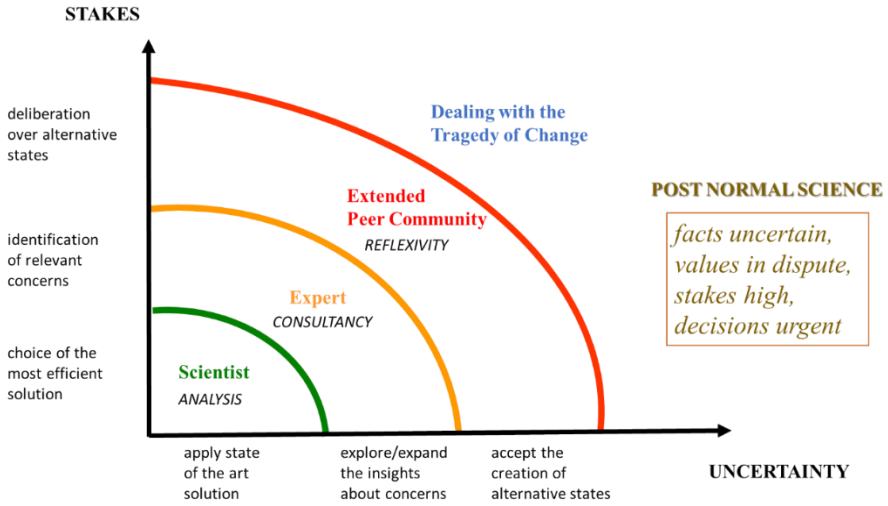

Figure 3. The iconic diagram of Post-Normal Science proposed by Funtowicz and Ravetz in relation to the different uses of science and roles of scientists in different situations.

Understanding the differences between these roles is essential to perceive the special role that scientists should play when asked to provide input about sustainability. The three roles indicated in the diagram are:

1. "Normal" scientist - when scientific input refers to an issue in which we can assume a low level of uncertainty and a clear definition of stakes (e.g., building a bridge). In this role, scientists are expected to apply known procedures. This case refers to a situation in which the available knowledge claims about how to build bridges are robust and uncontested. In this case, the pertinence and the rigor of the analysis are sufficient to guarantee the quality of the scientific work.

2. Expert - When the issue is more complex and it is essential to also consider the points of view of those that will use the scientific input, scientists have to play the role of the expert. They have to:

   i. identify the possible concerns that can be associated with the given action (e.g., a delicate surgery), i.e., the pros and cons of possible consequences,

ii. explicitly address the level of uncertainty of the expected results – e.g., the possibility and consequences of failure; and

iii. openly discuss with the user the prioritization over contrasting concerns in relation to the acknowledged existence of uncertainty.

In this role, scientists cannot decide on their own, they have to co-produce their decisions with those who will be affected by the choice(s) made.

3. Post-normal scientist - When facing a situation in which radical changes are needed that imply an adjustment of the identity of both the society (the cultural context) and the different agents involved in the decision process, things become different. In this situation "facts are uncertain, values in dispute, stakes high and decisions urgent" (Funtowicz & Ravetz, 1993, p. 744) and nobody, neither the social actors nor the scientists, can claim knowing what is the best thing to do, let alone having an effective method to prioritize contrasting concerns. In this case, the decisions have to be based on an informed deliberation of an extended peer community. However, this type of decision is no longer based on available knowledge claims (referring to something that does exist and has been experienced), but on something that does not exist and has to be created together by the coordinated action of society. In relation to this creation, particularly important are the emotions, feelings, hopes, and fears in determining the ability to maintain the current set of affective interactions. The society has to prioritize the protection of the social bonding. In this situation, the option of "fixing the external world according to our will" no longer exists because we simply do not have a robust, reliable and uncontested plan based on an uncontested agreement of "who we are" and "what we want to be". Rather we have to learn how to explore the option of "changing our identity and social practices in order to become more respectful of nature and more caring for each other".

Certainly, scientists can play a key role in this learning. However, they have to forget about the Cartesian dream and abandon the hegemonic use of orthodox neo-liberal narratives that see human society as distinct from nature. Scientists should help society to recognize that human beings must learn how to care for each other while living within the limits imposed by nature because to nature they belong.

4. Conclusions

It is time that developed societies accepted that we must learn how to go through the tragedy of change. We are part of nature and we have to co-evolve with nature. We simply cannot impose our will on nature, nor control her. In this dire

environmental and social crisis, it is important that scientists properly play their role. Rather than endorsing the hubris associated with the Cartesian dream of prediction and control, scientists should acknowledge the complexity of the sustainability predicament and flag the need for considering various different narratives and strategies, including relying more on our common sense and feelings. There is no shame in starting a discussion over the sustainability predicament with a sobering acknowledgment that we have a problem and that we do not know how to solve it. More silver bullets or the invisible hand of the market simply cannot solve our sustainability problems. Only a radical change in social practices based on a shared understanding that what society needs is less capital and more caring can put us on the path toward a more sustainable and equitable development.

Socrates warned scientists to be wary of their own ignorance. In sustainability science, this advice is particularly pertinent. It is not the task of the scientist to control nature but to help society understand that we are part of it. Scientists should interact with the rest of society to co-generate a collective reflection on the existence of natural limits and discuss with all societal actors 'desirable' future pathways. This special issue shows creative ways of how this can be pursued in practice.

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Position Paper

Affective Ecology as development of biophilia hypothesis

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Keywords: biophilia hypothesis; biophilia phylogeny; biophilic design; Gaia hypothesis; green mindfulness; naturalistic intelligence.

Abstract. *Affective ecology is the branch of ecology that deals with the cognitive and emotional relationships that humanity and Gaia establish between themselves. In the last ten years, affective ecology has engaged above all in the experimental verification of the biophilia hypothesis and in defining the two fundamental constructs of biophilia: fascination and affiliation. The definition of such constructs allows us to estimate more precisely the psychological effects of biophilia. Fascination for Nature triggers the restoration of cognitive skills after mental fatigue, while the feeling of affiliation for Nature has a stress-reducing effect. The experimental outcomes allow us to design an ideal biophilic environment, able to stimulate fascination and affiliation for Nature. A biophilic environment is the ideal environment for developing naturalist intelligence. The future perspectives of affective ecology concern the search for high biophilic quality environments, which can be both inner environments, as in the case of Green Mindfulness in ecopsychology, and outer environments as in the case of Biophilic Design in architecture.*

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1. Introduction

My love for Nature[1] is not rational. I am attracted to life. It was obvious to me to choose Life Sciences at university. The knowledge of biology allowed me to love Nature even more. However, as a university student I had great difficulty accepting a science that rejected my love for Nature. This rejection by the mainstream aroused in me a desire to integrate my emotional side into science. This is how *affective ecology* was born.

It was not an easy path. But on my journey, I met many other scientists "on the road", including researchers from the L-TER Network (Long-Term Ecological Research Network) who reflect on topics and goals of science and explore new ways of doing research and communicating ecology. The questions posed by researchers of the L-TER Network are at the basis of research in affective

[1] In this article I will use the word "Nature" with a capital "N" to indicate the biosphere and abiotic matrices (soil, air, water) where it thrives. In addition to being a gesture of respect towards an entity that transcends us as human beings, this will avoid confusion with "nature" (with the lowercase "n") understood as the intrinsic quality of a certain creature or a certain phenomenon.

ecology. Can we integrate science with other forms of description of the world? Are we aware of the role that emotions play in building bonds with Nature? The meeting at Feudozzo, Italy (12-16 September 2019) organized by the Italy L-TER Network was a moment of reflection on the last ten years of research. It provided a stimulus to look for new ways of doing science that consider emotions that Nature gives us, respecting the tradition that goes from Darwin (1872) to the present day (Longo, 2014).

2. Affective ecology ten years ago

Affective ecology is ten years old. The first time I spoke publicly about "affective ecology" was at the workshop «I linguaggi della sostenibilità. Il museo scientifico per un dialogo nuovo con, dentro e a proposito della Natura»[2], which took place from 24 to 27 February 2011 at the Civic Museum of Zoology in Rome and at Villa Adriana (Tivoli, Rome). For ten years I have dedicated myself to this branch of ecology, which deals with the emotional bond that ties up humanity to Nature (Barbiero, 2017). I have studied (Colucci-Gray et al., 2006), undertaken research (Barbiero, 2009), conducted experimental tests (Barbiero 2011; 2014) and suggested hypothesis (Barbiero and Berto, 2021). After ten years, perhaps the time has come to take stock of the situation, starting from the two scientific hypotheses on which the affective ecology is founded: the Gaia hypothesis and the biophilia hypothesis. Over the span of ten years these two hypotheses have evolved, enriched with data, their explanatory power has been clarified and connected to other theories and models, such as the Stress Recovery Theory (Ulrich, 1991) the Attention Restoration Theory (Kaplan, 1995) and naturalistic intelligence in Multiple Intelligence Theory (Gardner, 1999).

2.1 The Gaia hypothesis

Gaia is the system of living organisms (biosphere) interacting with air (atmosphere), water (hydrosphere) and soil (pedosphere). Gaia is the biosphere and the matrices in which it thrives (Volk, 1997, pp. 99-124) that evolve over time (Lovelock, 1988). Although Gaia and Nature are often used interchangeably, Gaia does not coincide with Nature. Nature emerges from the coupling of the metabolism of living organisms with the outer environment, which *continually* reshapes the habitability conditions of Gaia (Lenton, Dutreuil and Latour, 2020). Nature is Gaia at a certain time in the history of life on the planet. Nature belongs to Gaia

[2] "Sustainability languages. The scientific museum for a new dialogue with, within and about Nature"

as a frame belongs to a film. The history of Gaia is full of events that reduced the size of the biosphere. In the Phanerozoic alone, there are at least five major mass extinction events - not surprisingly called transitions - from which Gaia has always recovered, even if the Nature of that era has completely disappeared. This distinction helps us to understand that *Homo sapiens* can modify the environment and harm Nature as we know it, but it cannot harm Gaia. For example, Gaia has not always been hospitable to aerobic organisms. Gaia today (Nature during Cenozoic) is hospitable to respirators, but originally (Nature during Archean) was not. In the future, Gaia may no longer be hospitable to aerobic organisms. Gaia is Gaia. Nature is the epiphany of Gaia at a certain moment in her evolutionary history.

Life on Earth has been flourishing continuously and seamlessly for 3,800 million years. Since liquid water is essential for life, we can deduce that in all this time the planet's mean surface temperature has always remained between 0° C and 100° C, which, at a surface pressure of about 1 bar, has allowed the presence of liquid water (Schwartzman, 1999). And this happened in a situation of progressive increase in the radiant power of the Sun (Watson and Lovelock, 1983). Geophysiology, literally the 'Gaia physiology', was born from this simple empirical datum. The experience gained by this young science has been essential in evaluating the possibility of life in exoplanets, that is, the planets that orbit outside the solar system and about which today we can have information with the aid of new telescopes (Schwieterman, 2018).

A frequent mistake is to think of Gaia as a living organism like us. Gaia is a living organism, but *sui generis*. In fact, living organisms are thermodynamically open systems, that is, they are crossed by energy flows and are characterized by exchanges of matter. Gaia, on the other hand, is a thermodynamically *closed* system and is crossed by energy flows (mainly the Sun) but cannot exchange matter with the surrounding environment. This forces Gaia's creatures to continuously recycle matter and this characteristic of Gaia has become a part of the great debate on sustainability (Volk, 1997). In the long term, only a system able to use the energy flows that cross the planet (renewable energy sources) and recirculating matter (recyclable materials) is sustainable, thus influencing many techno-industrial fields (Schlesinger and Bernhardt, 2013).

We still do not know many details on how Gaia works. However, we know the main laws that determine its general functioning (Kump, Kasting, and Crane, 2011). The study of Gaia and its laws proposes once again the theme of contemplation of Mother Earth, a powerful archetype able to inspire human behaviour (Liu et al., 2019). Perhaps today we no longer need to anthropomorphize Gaia in

Mother Earth. Perhaps today contemplation of it is enough, as in the case of the Apollo 8 astronauts who in December 1968 took the first photograph of the Earth from space (**Figure 1)**.

Figure 1. The first photograph of the Earth with a view from space taken by the Apollo 8 crew (Frank Borman, James Lovell and William Anders) in December 1968.

The beauty of this blue jewel, immersed in dark and cold space, is now an icon of our era, whose psychic function for many is no different from the one that traditional icons have for Orthodox Christian monks. For some scientists, Gaia's iconic function continues to be a problem. For others it is becoming a resource for psychological (Fellows, 2019) and spiritual (Christie, 2013) research, on a track already traced by ecopsychology (Roszak, Gomes, and Kanner, 1995) and by the ecology of mind (Bateson, 1972). To me Gaia has been a profound and primitive psychological experience (Barbiero, Gasparotti, and Baruzzi, 2015).

In the same way as ten years ago, I continue to think that Gaia is a resource for biophilia and the development of naturalist intelligence (Barbiero, 2011).

2.2. The Biophilia hypothesis

Biophilia is our emotional bond with life. Biophilia is the combination of two Greek words: love (*philia*) for life (*bio*). It was coined twice, independently, by the German psychologist Erich Fromm (1964) and the American biologist Edward O. Wilson (1984). Fromm uses the term biophilia to describe the *psychological* orientation to be attracted to all that is alive and vital (Fromm, 1964). Wilson uses the term biophilia to describe the *evolutionarily* adaptive trait of being attracted to what is alive and vital (Wilson, 1984). Biophilia is innate, but it is not instinctive. Being innate, biophilia is the manifestation of a genomic structure that has overcome the screening of natural selection and can therefore be studied from an evolutionary (phylogenetic) perspective. However, not being instinctive, biophilia must be stimulated in order to develop its full potential and can therefore be studied from a psycho-pedagogical (ontogenetic) perspective. The two perspectives, phylogenetic and ontogenetic, complement each other and offer a theoretical horizon for the experimental verification of the biophilia hypothesis (Barbiero and Berto, 2021).

3. Theoretical biophilia

Biophilia is an innate predisposition to learn from the living world. In other words, we are genetically predisposed to interaction with Nature. Predispositions to learn are very important for *Homo sapiens*. Babies are extraordinarily inept at birth and spend a very long inculturation phase, during which they learn the necessary behaviours to survive. Being quick and effective in learning confers an evolutionary advantage, which is still rewarded in school systems all over the world. We can consider biophilia a construct of the human temperament that contributes, together with character, to form personality. Temperament represents a series of innate aspects of personality, derived directly from our evolutionary history and not mediated by culture (Cloninger, Svrakic, and Przybeck, 1993). Although some researchers show resistance to fully understanding the evolutionary heritage of biophilia (Joye and van den Berg, 2011; Patuano, 2020). But an honest analysis cannot leave out the reconstruction of human evolutionary history. Studying biophilia in its phylogenetic (evolutionary) traits will help us better understand biophilia in its ontogenetic (psychological) traits.

3.1 Biophilia phylogeny

Biophilia has been defined as "our innate tendency to focus upon life and life-like forms and, in some instances, to affiliate with them emotionally" (Wilson 2002, p. 132). According to E.O. Wilson, "biophilia is not a single instinct but a complex of learning rules that can be teased apart and analyzed individually. The feelings molded by the learning rules fall along several emotional spectra: from attraction to aversion, from awe to indifference, from peacefulness to fear-driven anxiety" (Wilson, 1993, p. 31). Attraction to Nature is biophilia, aversion to Nature is biophobia (Ulrich, 1993). Over the course of evolution, humanity has had to face the hostile forces of wild Nature. The rules of learning biophilia and biophobia are rooted in the genetic heritage of our species in relation to their contribution to improving human efficiency in the search for resources and shelter. Wild environments trigger two basic types of physiological reaction: (1) the 'fight-or-flight' response, which results in hyperactivity of one of the two branches of the autonomic nervous system, usually an over-stimulation of the sympathetic nervous system (Shimuzu and Okabe, 2007), which is related to the concept of biophobia (Ulrich, 1993); and (2) the 'rest-and-digest' response, which manifests itself as the cooperation of the two branches of the autonomic nervous system, with a prevalent influence of the parasympathetic nervous system. The balance of the two branches of the autonomic nervous system ensures a better long-term resilience of the individual (Harvard Medical School, 2018).

Biophilia evolved in the Palaeolithic era. For about 95% of our evolutionary history, humans have survived by adopting the hunter-gatherer lifestyle. Human beings have thus perfected a set of adaptive responses to different wild environments - mainly the savannah (Orians and Heerwagen, 1992) - aimed at recognizing the quality of an environment in terms of resources and shelters. Some environmental preferences are based on innate learning rules derived from the struggle for the survival of our ancestors and today they form the primary and deepest core of our biophilia (Berto et al., 2015). After the invention of agriculture and breeding about 14,000 years ago (Arranz-Otaegui, et al. 2018), most of the human population became progressively sedentary (Tattersal, 2008, pp. 125-164). Shelters became increasingly permanent, and the first villages were formed (Diamond, 1997). Farmers were forced to protect their crops and farm animals from predators present in wildlife, including other humans (Spinney, 2020). The food supplies accumulated in the village could tempt attackers and this led to the need to protect the villages (Spinney, 2021). Neolithic farmers began to distinguish between rural (good) and wild (bad) Nature. The male archetype also changed. To highlight their fitness, young males were increasingly driven to abandon the

'hunter' lifestyle, to take on that of the 'warrior' (Gimbutas, 1989). In the Neolithic period, which covers approximately 5% of humanity's evolutionary history, biophilia was partially adapted to new cultural demands. An example is proxemics. In the Paleolithic period, the bands of *Homo sapiens* were numerically few, and encounters outside one's clan were rare and sporadic. During the Neolithic period, village life needed a level of socialization that required hitherto unknown physical proximity, to which we are still not fully adapted (Larsen et al., 2019). This could explain, for example, why many people look for outdoor spaces in Nature where human presence is rare.

Finally, only in the last 250 years - a period irrelevant from an evolutionary point of view: less than 0.2% of the evolutionary history of humanity - humans have developed their inclination to transform the environment permanently and irreversibly (Crutzen, 2006). During this period, urban agglomerations gradually become larger and more densely populated. Compared to the wild Nature in which humans evolved, the countries and cities now inhabited by 55% of the world population (Worldbank, 2019) are characterized by an increase in population density and a decrease in green spaces (Beatley, 2011). Since biophilia is a predisposition to learn, if natural stimuli are lacking, this tends to atrophy (Wilson, 1993; Clements, 2004).

The biological evolution of humanity took place in the wilderness. Our genetic predisposition to quickly recognize environments rich in resources and suitable for survival, has favoured the psychological preference for such environments, which are perceived as "restorative" (Barbiero, 2011; Barbiero, 2014). Humans may have learned that resource-rich environments are reassuring (biophilic) and can help restore from mental fatigue more than others (Berto, 2014). Furthermore, restoring attention in shorter time spans may have conferred some evolutionary advantage (Kaplan, R. and Kaplan S., 1989, p. 181). From this point of view, the perceived restoration capacity, understood as the (measurable) ability of people to focus on the restorative characteristics of the environment, could be one of the innate learning rules of biophilia (Wilson, 1993). Although the first break of the Neolithic and above all the second break of the Industrial Revolution had a strong influence on inculturation processes, the predisposition to learn from Nature has probably remained the same. But the kind of Nature from which to learn has changed. There are many indications that wilderness has remained in depths of the human psyche (Pinkola Estés, 1992).

3.2 Biophilia ontogeny

E.O. Wilson (2002, p.132) identifies two conditions/constructs that are necessary for biophilia recognition. The first condition is that life has the power to shift the focus (*fascination*). The second condition is that, in certain circumstances, an emotional bond is created with a life form (*affiliation*).

Before going into the merits of the experimental verification of the constructs of love for life (biophilia), it is necessary to clarify that life (the *life*) does not coincide with Nature (*Life*). In the first case, life is the class of property that is common to all living things. Nature (*Life*) is life *plus* the abiotic environment in which it thrives. Nature emerges from the coupling of the metabolism of living organisms with the outer environment, which continually reshapes the habitability conditions of Gaia (Lenton, Dutreuil and Latour, 2020). Gaia's living conditions vary over time. In the Archean, for example, Gaia's Nature was totally unsuitable for the life of plants and animals. It took billions of years before the coupling of the metabolism of living organisms with the outer environment managed to create a Nature where plants and animals could thrive.

Life can thrive in totally artificial environments, such as a zoo or a laboratory. However, the psychic effects are very different. Environmental psychology distinguishes three types of contact: direct, indirect, and symbolic. The *direct* contact with Nature is the encounter with animals and plants in their natural habitat. The *indirect* contact with Nature is the encounter with animals and plants in artificial environments (farms, zoos, botanical gardens). The *symbolic* contact with Nature is the virtual encounter with animals and plants (books, documentaries, videos, audio). In ecological terms, it can be said that *life* corresponds to a biological *community*, Nature (*Life*) to an *ecosystem*. It is therefore possible to reformulate Wilson's definition, in this way: "biophilia is our innate tendency to focus upon Nature and in some instances to affiliate with some of its components emotionally".

This leads to an important question which can only be mentioned here: is there also a *geophilia* alongside *biophilia*? There is no doubt that the abiotic components (for example: the mountain, the sea, the river, the lake) or the atmospheric events (for example: the clear sky, the clouds, the rain) influence our mood and our psychic state. However, we still do not know whether the cognitive effects of biophilia can also be extended to geophilia (Elena Ferrero, personal communication). The hypothesis should certainly be taken into account, considering that historically there are testimonies - such as those of Hildegard of Bingen (Newmann, 1987), of Francis of Assisi (Stratman, 1982; Barbiero, 2016) and, in

more modern times, of Gary Snyder (Chowka, 1977) - attesting that the clear distinction between 'living' and 'non-living' is artificial. In any case, the abiotic environment is also important for another reason. It seems that the same living creature can arouse different emotions if contemplated while it is in its natural abiotic environment or in an artificial environment and the more the artificial environment approaches that of the natural habitat, the more our emotion becomes powerful (Powell and Bullock, 2014).

A careful analysis of the biophilia ontogeny leads to two important considerations. The first consideration is that if Nature exerts its fascination power over the human being, then Nature is active in this relationship, while the human being is passive. Since Nature is an epiphany of Gaia, then Gaia is an active agent on the human psyche. Gaia's metaphor as Mother Earth thus takes on a significant psychological meaning, considering that the Great Mother is considered a fundamental archetype in analytical psychology (Neumann, 2015). The second consideration is that biophilia is innate but not instinctive. It should therefore be stimulated and educated. From an educational psychology point of view, biophilia represents a psychic potential that can be enhanced so that it contributes to the flowering of different forms of intelligence, inter alia naturalist intelligence (Gardner, 1999, pages 48-52). Correlating the stages of cognitive development (Santrock, 2008, pp. 211-216) with the stages of environmental knowledge (Barbiero and Berto, 2016, p. 67) and the latter with the values associated with Nature (Kellert, 2002; Barbiero and Berto, 2016, p. 79) gains importance.

4. Experimental biophilia

In 2011 it was clear that if the biophilia hypothesis had ever had any chance of becoming a reliable theory, then experimental research could very usefully focus on the two constructs prefigured by Wilson (2002): *focus upon* and *affiliation*. Fortunately, environmental psychology had already identified the two biophilia constructs. The construct "focus upon" is called *fascination* and is defined as the "involuntary attention triggered by Nature" (Berto, 2005). The construct of "affiliation" has been defined as the *connectedness to Nature*, sometimes called *relatedness to Nature* (Nisbet, Zelenski, and Murphy, 2009), understood as the "individual emotional experience with Nature" (Mayer and Frantz, 2004). The important (and decisive) fact for our experimental verification is that both *fascination* and *connectedness to Nature* are constructs measurable with appropriate psychometric scales, the 'Perceived Restoration Scale' (PRS; Hartig et al., 1996) and the 'Connectedness to Nature Scale' (CNS, Mayer, and Frantz, 2004), respectively. From

here on 'fascination' will be used to indicate the involuntary attention triggered by Nature and 'affiliation' to indicate the connectedness to Nature (**Table 1**).

Biophilia	*Environmental Psychology*	*Psychometric scales*
Focus upon	**Fascination**	PRS - Perceived Restorativeness Scale (Hartig et al. 1996)
Affiliation	Connectedness to Nature	CNS - Connectedness to Nature Scale (Mayer and Frantz, 2004)

Table 1. Comparison between the biophilic constructs proposed by E.O. Wilson (2002, p.132) and the corresponding constructs identified in environmental psychology, with the related psychometric scales. The name chosen for each construct in this article is in bold.

4.1 Fascination, and the Attention Restoration Theory

Stephen and Rachel Kaplan devoted their scientific career to studying the mechanisms of restoration of direct and sustained attention after mental fatigue. They identified four constructs that promote the restoration of direct and sustained attention: 1) *being away*; 2) *fascination*; 3) *extent*; 4) *compatibility* (Kaplan, 1995). Particularly interesting for my studies was the second construct: *fascination*. Fascination triggers involuntary attention, an effortless form of attention, and allows direct attention to restore. In a series of experimental tests, Berto and I measured the time spans of restoration of the direct and sustained attention of the children after a mental effort in different environments and situations. We found that children, if they were left free to play in the woods, had shorter attention restoration times than children left free to play in the school yard. Furthermore, we also found that children perceived the restorative qualities of an environment and preferred more restorative environments (Berto, et al., 2015b). This series of experimental observations allowed us to define it as the *Standard of Étroubles*, from the name of the small village in the Valle d'Aosta (Italy) where the outdoor observations were conducted (Barbiero and Berto, 2016, pp. 196-200). The *Standard of Étroubles* establishes a ranking in the restorative power of environments. In general, after mental effort, a restorative process is more effective in a natural environment (woods) than in an artificial environment (classroom). With the same environment (classroom), a restorative process is more effective if the child can use "mindful silence" (Berto and Barbiero, 2014). Subsequent experimental observations then confirmed the *Standard of Étroubles*, noting how Nature

exercises a restorative fascination of cognitive faculties (Kuo, Browning, and Penner, 2018; Chang et al., 2020) and that fascination is closely related to environmental preferences (Wang et al. 2019).

4.2 Affiliation, and the Stress Recovery Theory

The second construct of biophilia is *affiliation* (Wilson, 2002, p. 132). Defining the feeling of affiliation is difficult. The root of the feeling of affiliation seems to originate in "our capacity to experience empathy with other creatures and respond to their concerns as our own" (Goodenough 1998, p. 127). In the first instance, affiliation could correspond to the ability of creating an emotional bond with life. Affiliation could be the equivalent of the construct "connectedness to Nature" (Mayer and Frantz, 2004). In this case, the sense of unity of the word 'affiliation' would reveal all the psychic potential of the relationship between Human and Gaia. The etymological origin of the word 'affiliation' is interesting. It derives from the Latin *ad filius* and indicates a process of adoption. 'Affiliation' literally means "feeling like a son". Therefore, thinking of a parent becomes natural. In this case Mother Earth (Gaia) or more likely a limited epiphany thereof. However, affiliation is not automatic. While fascination is a passive and involuntary phenomenon, affiliation requires a willingness to desire a relationship with another non-human creature. Humans like establishing an emotional relationship with a pet because this type of affiliation reduces stress. In his famous *Why Zebras Don't Get the Ulcers* Robert Sapolsky summarized the crucial psychological variables that modulate the intensity of psychological stressors in primates: (1) outbursts of frustration; (2) social support; (3) predictability; (4) control (Sapolsky, 2004, pp. 234-248). Interestingly, a pet is an excellent modulator of all four psychological stressors. Under certain conditions Nature (*rural* Nature) can offer help reduce stress. It is therefore reasonable to assume that a higher connectedness to Nature tends to favour faster recovery from stress, as Roger Ulrich has empirically pointed out. Initially, Ulrich showed that simple eye contact with Nature had the effect of speeding up recovery from a state of stress (Ulrich, 1984). Ulrich later extended this observation to other sensory functions in his Stress Recovery Theory (Ulrich, 1983; Ulrich et al. 1991).

4.3 Fascination is a 'state', Affiliation is a 'trait'

In the experimental observations that led us to the *Standard of Étroubles*, we repeatedly found that *fascination* - measured as the restorative capacity perceived by children - increased during a day spent in a wooded environment. The feeling of affiliation, however - measured as a connectedness to Nature - remained

unchanged (Berto, Pasini and Barbiero, 2015). This seems reasonable because fascination is a relatively immediate response to a natural environment. Kuo, Browning, and Penner (2018) offer a demonstration which, in a series of experimental observations, managed to trigger a restorative process, evocatively defined as "refuelling students in flight". This suggests that *fascination* is a 'state' that varies in relation to the characteristics of the environment, to its restorative qualities (Purcell et al., 2001; Berto, 2007). *Affiliation* instead seems to be a 'trait' of the temperament: one feels connected to Nature regardless of the environment where we are (Mayer and Frantz, 2004). *Affiliation* can vary, but requires more time, a frequent and direct exposure with Nature (Berto et al., 2018) and a specific educational project aimed at building naturalist intelligence (Meyer, 1997; Nolen, 2003).

5. Building a Naturalist intelligence

Biophilia is a predisposition to learn based on the constructs of fascination and affiliation. Rapid and effective learning offers an evolutionary advantage, and it is therefore probable that fascination and affiliation have consolidated over time as a psychobiological potential of naturalist intelligence.

5.1 The 'environmental concerned' personality

Howard Gardner defined naturalist intelligence as the ability of "recognizing flora and fauna, making other consequent distinctions in the natural world and using this ability productively" (Gardner, 1995). Gardner originally identified seven intelligences in his Multiple Intelligence Theory (1983). Only fifteen years later he recognized, and subsequently integrated, naturalist intelligence into his theory (Gardner, 1999). Naturalist intelligence seems easy to understand intuitively. However, it is a rather complex construct. Although it consists of the ability of processing information and spreading environmental knowledge without including any emotional capacity (Gardner and Moran, 2006), Gardner admits that naturalist intelligence is an expression of "what Wilson has termed «biophilia»". According to Gardner "the naturalist intelligence comfortable in the world of organisms and may well possess the talent of caring for, taming, or interacting subtly with various living creatures" (Gardner 1999, p. 49). The ability to "care for" and to "interact subtly" are manifestations of an affective and emotional connectedness to Nature and correspond to Wilson's affiliation. Basically, naturalist intelligence feeds the affiliation which, in turn, strengthens the desire

to know Nature and prepares for new experiences, in a virtuous experience-reflection-experience circuit (Kahn, 1997; Gill, 2014; Adams and Savahl, 2017; Tillmann et al., 2018). Gardner points out that "biologists' biographies routinely document an early *fascination* with plants and animals" (Gardner, 1999, p. 50, my italics). Although no evidence is available in the literature for a relationship between attention restoration and naturalist intelligence, biologists' biographies show that an "early fascination" (fundamental for restoration) is crucial for the development of naturalist intelligence. Finally, Gardner notes that the biographies of famous naturalists - such as, for example, Rachel Carson (1962) or E.O. Wilson (1994) - show that a mature naturalist intelligence tends to be sensitive to environmental conservation by strengthening the individual's pro-environmental behaviour.

Berto and I proposed a model that correlated affiliation (measured with "connectedness to Nature"), fascination (measured as "perceived restoration"), environmental knowledge and commitment to the environment. The model was designed to highlight how pro-environmental behaviour could be influenced by the cognitive and affective constructs of biophilia (Berto and Barbiero, 2017a). Below we propose a review of that model (**Figure 2**) in which environmental knowledge is replaced by naturalistic intelligence and fascination is also proposed as a motivator for pro-environmental behaviour.

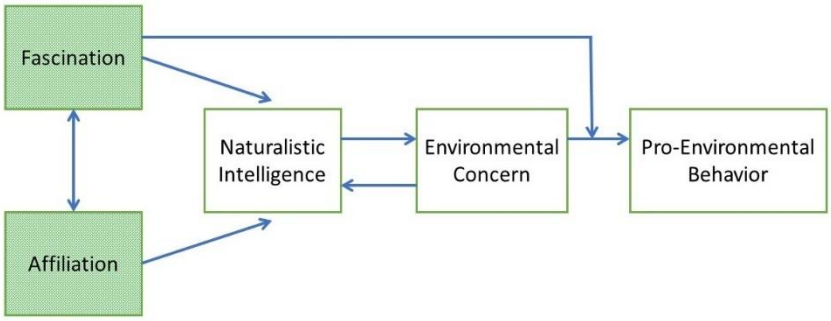

Figure 2. Model that relates the two constructs of biophilia (in green) – fascination and affiliation – and naturalist intelligence, environmental concern, and pro-environmental behaviour (Barbiero and Berto, 2018).

5.2 The biophilic qualities of the environment

Cultivating intelligence always requires an appropriate environment. This is especially true for naturalist intelligence, which needs a natural environment stimulating biophilia. It is therefore important to identify the qualities that stimulate biophilia. The term "biophilic qualities" refers to the set of physical, aesthetic, and functional characteristics of an environment which are perceived as restorative. We know that the restorative power of an environment corresponds to fascination, one of the fundamental constructs of biophilia. To this end, Berto and I have developed an instrument, *Biophilic Quality Index* (BQI, Berto and Barbiero, 2017b), to synthetically measure the characteristics of an environment according to the restorative factors described in Attention Restoration Theory (Kaplan, 1995). When we tried to investigate whether there was a correlation between fascination and affiliation, we discovered that the correlation did exist and it was mediated by the "biophilic quality" of the environment. We compared four different natural parks to which were assigned two levels of "biophilic quality" (high or low) based on two factors: the distance from the subject's residence (*being away*) and the restorative potential (*fascination*) evaluated with the *Recreation Opportunity Spectrum*, a quality assessment system for natural parks (Clark and Stankey, 1979). We evaluated the affiliation with Nature (with the CNS) and the fascination (with the PRS) of each visitor to each park. The study showed that when the environment is characterized by a low biophilic quality (for example, an urban natural park) and the visitor has a low level of affiliation with Nature, then the environment is perceived as highly restorative. On the contrary, when the visitor has a high level of affiliation with Nature, then the environment characterized by a low biophilic quality is perceived as not very restorative. Only when the environment is characterized by a high biophilic quality (for example, a wild natural park), subjects with a high level of affiliation with Nature can fully perceive the restorative potential of the wild environment. The subject with high affiliation seems to have a greater ability to discern restorative environments. Feeling strongly connected with Nature (affiliation) makes you more sensitive to the restorative power (fascination) of an environment and allows you to recognize environments with the best biophilic qualities. A more efficient ability to recognize the most restorative environments could represent an important evolutionary advantage. This experimental observation further reinforces the idea of the evolutionary origin of biophilia.

5.3 Which Nature?

Being in Nature makes you feel good (White et al. 2019). But Nature is not the same everywhere. Some types of Nature seem to stimulate biophilia better than others and are preferred. Other types of Nature seem to stimulate biophobia and are avoided. In general, people seem to be more fascinated by the type of Nature that corresponds to their feeling of affiliation. As a first approximation it can be observed that people with a strong feeling of affiliation are more easily fascinated by wild Nature, while those with a more modest feeling of affiliation tend to prefer rural Nature (Berto et al. 2018). Since rural Nature is usually characterized by a higher population density than wild Nature, it is possible to propose a classification of Nature based on the population density of the areas covered by our studies (**Table 2**).

Type of Nature	**Density (inhabitants/Km²)**	**Examples (inhabitants/Km²)**
Urban	More than 500	Aosta (1,587.7) Pont-Saint-Martin (539.0)
Rural	From 500 to 10	Saint Vincent (222,8) Étroubles (12.5)
Semi-wild	From 10 to 2	Rhêmes-Saint-Georges (4.7) Gressoney-La-Trinité (4.5)
Wilderness	Less than 2	Valsavarenche (1.2) Rhêmes-Notre-Dame (0.9)

Table 2. Classification of Nature based on the population densities of different administrative units. The examples in the last column on the right refer to some settlements in the Valle d'Aosta, Italy.

A first research track could verify if people with high affiliation with Nature really tend to prefer wild Nature, while people with lower affiliation tend to prefer rural Nature. If the observation is confirmed, then we can ask ourselves: why does an affiliation with higher Nature correspond to a desire for a wilder Nature? The answer may once again be evolutionary. Affiliation is a 'trait' of the temperament that has evolved and was successful in the Palaeolithic, when only wild Nature existed. However, the human evolutionary experience with Nature had two breaking moments: the Palaeolithic-Neolithic passage and the Neolithic-Urban passage. An adaptation that has been successful in the relationship with wild Nature may no longer be as effective when the prevailing environment is rural.

The biophilic trait may have entered an adaptation and exaptation cycle (Gould and Vrba, 1982) to develop new forms of adaptation and promote its better use based on the demands of the new Neolithic lifestyle. Indeed, when rural Nature appears, wild Nature becomes an 'enemy', to be removed and rejected. Affiliate feelings are therefore reserved only for pets. An example is our ambiguous relationship with the species *Canis lupus*. Wolf is the wild version of *C. lupus* and it was the only known form in the Palaeolithic. The Palaeolithic Human feared the wolf and admired it, so much so that he made it his own archetype. A Neolithic Human continued to fear the wolf, but rejected it, while protecting the dog, the rural variant of *C. lupus*, because it was useful for his new lifestyle.

Palaeolithic humans lived in small nomadic communities in large areas, population density was low, and encounters were rare. Neolithic humans lived in stable villages in narrower areas, where population density was higher, and encounters were more frequent. The affiliation with wild Nature could be a temperament trait with a pleiotropic effect on the perception of a restorative environment and on the perception of the population density of a certain area. For example, the usual landscape for a Palaeolithic human being was devoid of visible centres of human aggregation. It is therefore presumable that restorative environment was perceived without such centres. For a Neolithic human being, on the other hand, landscape was characterized by visible centres of human aggregation, which in fact served as a landmark and which often constituted the final goal of a transfer. Therefore, the restorative environment was presumably perceived with such centres.

The pleiotropic effect appears more evident in the passage from Neolithic to Urban, from countryside to city. In an urban environment, usual landscape is apparently devoid of Nature. Nature is almost invisible and cannot support restorative processes. Lifestyle changes, naturalist intelligence is no longer necessary, and the feeling of affiliation fades further way, without ever becoming completely extinct. If this hypothesis is correct, three fundamental phylogenetic experiences can be identified (**Table 3**): Palaeolithic, Neolithic and Urban. To which three types of affiliation with Nature, respectively the paleo-type, the neotype, and the urban-type, correspond.

Phylogenetic experience	Type of privileged Nature	Characteristics of the type of affiliation
Palaeolithic	Wild	Connectedness to wild Nature. Circadian rhythm of life. Sober lifestyle and essential nutrition. Preference (and fear) for plants and wild animals.
Neolithic	Rural	Connectedness to rural Nature. Seasonal rhythm of life. Natural lifestyle and organic nutrition. Preference (and no fear) for plants and pets.
Urban	Invisible	Disconnection from Nature. Urban life rhythm. Chemical and circus lifestyle (Galtung, 1984) and feeding with industrially manipulated food. No preference for plants or animals.

Table 3. Phylogenetic experiences of affiliation, type of privileged Nature and fundamental characteristics of affiliation of the corresponding psychological type. See text for details.

The *paleo-type* corresponds to the Palaeolithic human being who knew only wild Nature. He needed to oppose Nature's hostile forces. He was afraid of Nature and in his daily search for resources he prepared himself for fight-or-flight. However, in everyday life these stressful situations happened rather rarely. Still today, hunter-gatherer communities spend no more than 2-3 hours a day researching and preparing food (Sahlins, 2017). Our ancestors therefore had long moments of rest-and-digest, which lead instead to enjoying Nature and the feeling of affiliation (Moreton, Arena, and Tiliopoulos, 2019). Probably rest-and-digest immersed in wild Nature constitutes the phylogenetically oldest nucleus of our biophilia.

The *neo-type* corresponds to the Neolithic human being, who distinguished rural Nature from wild Nature. The wild Nature that obliges fight-or-flight is removed and circumscribed, favouring instead rural Nature, where growing and breeding in a protected environment was possible. Although it takes a lot of time and work, growing plants and rearing pets can be seen as a kind of attempt to prolong the rest-and-digest.

Finally, the *urban-type* is the human being who lives in the cities, where even rural Nature is removed, and where the presence of animals only for affective support is allowed, especially dogs and cats. Nature becomes 'invisible' to the naked eye. Nature is always present as microorganisms, but this Nature can apparently be ignored, unless it becomes particularly aggressive.

All three phylogenetic experiences of affiliation are probably present and settled in each human being. However, since affiliation is a 'trait' of the temperament, it is possible to hypothesize a prevalent experience that gives rise to a specific relationship with Nature. If this hypothesis is correct, then each type of

affiliation corresponds to a prevalent behaviour, which refers to the type of evolutionary experience. Let us take nutrition, for example. In the Palaeolithic, humans had a very sober lifestyle compared to today's standards, with a very frugal type of diet and we can assume that the paleo-type continued to prefer this type of feeding. In the Neolithic, the lifestyle became more lavish. The abundance of food and the continuity of supplies allowed to take greater care of the food. Thus, food traditions were born. Such traditions today are structured in 'natural' feeding patterns (organic, macrobiotic, vegan, etc.), which we can assume are those favoured by the neo-type. In an urban environment, contact with Nature is lost, lifestyle conforms to very intense urban rhythms (Patuano, 2020), which tend to point towards what Johan Galtung calls "chemical and circus lifestyle", where natural stimuli are replaced by chemical stimuli (lights, sounds, alcohol, drugs) or by collective circus moments (social or sporting events) which have an anti-stress function (Galtung, 1984). Diet also suffers from this. So, we can assume that the *urban-type* is more willing to accept manipulated or fast/junk food.

6. Future Perspectives: high quality biophilic environments

The Urban lifestyle has attenuated our contact with Nature. Nature continues to fascinate us (state), but we have loosened the feeling of affiliation (trait) with wild Nature. Sporadicity of encounters no longer stimulates our biophilia which predisposes us to learn from Nature, and biophilia tends to atrophy. It is foreseeable that the phenomenon of disconnection from Nature will tend to accentuate. In 2007, the urban population surpassed the rural population for the first time in human history. Forecasts for 2050 are that 75% of the population will live in the city (Worldbank, 2019). From a certain point of view this is good news. If human presence in rural areas decreases, it is foreseeable that wild Nature will tend to widen its spaces. Larger habitats will increase the chances of survival of wild species that are now threatened with extinction. However, people living in the city will have less and less chance of connecting with Nature. It therefore becomes important to create an environment as stimulating as possible for our biophilia. We have seen that fascination has a restorative effect on attention and on the cognitive system in general and affiliation has a recovery effect on stress and on the limbic-emotional system in general. The research hypothesis for affective ecology is therefore to verify if an adequate environment can offer stimuli to biophilia. Here I propose two research paths, oriented respectively toward the inner psychic environment (*Green Mindfulness*) and the outer natural environment (*Biophilic Design*).

6.1 Inner environment: Green Mindfulness in Ecopsychology

Finding a way to stimulate biophilia, even when we cannot immerse ourselves in Nature as we wish, is necessary to reinforce the emotional bond with Nature. It can be useful to cultivate a mental attitude that allows us to maintain over time an *inner environment* - made up of thoughts and emotions - conducive to the constructs of biophilia, fascination and affiliation: an ecological awareness (Barbiero, 2017, pp. 185-209). A promising research track is *Green Mindfulness*. Mindfulness is an attitude that is cultivated through a meditation practice developed starting from the Buddhist experience, oriented toward bringing the subject's attention to focus on the present moment in a non-judgmental way. The Buddhist tradition has developed practices to cultivate moments of awareness (*mindful*), with the goal of becoming a stable state of awareness (*mindfulness*).

Mindfulness appears to have effects on the anatomical-physiological architecture of the brain (Siegel, 2007), on the areas of the prefrontal cortex and the insula. Sara Lazar has highlighted that people who practice *vipassanā* meditation tend to maintain the thickness of the prefrontal cortex and insula layer almost intact, while in non-practicing people, the corresponding cerebral cortex layer thins with age (Lazar et al., 2005; Hölzel et al., 2011). It is interesting to note that the prefrontal cortex has a regulatory function of the attention and emotional balance, while the insula modulates the activity of the two branches of the autonomic nervous system (**Figure 3**).

Cortical area		Attributed functions
Dorso-lateral prefrontal cortex		Attention, memory, synthesis ability
Ventro-medial prefrontal cortex		Emotional balance, empathy, intuition, fear
Insula		Enterocceptive awareness, sympathetic/parasympathetic balance

Figure 3. Relationship between cortical area and presided function.

Over time, some practices have been standardized as mindfulness-based interventions (MBIs). The standardization of MBIs allows for a more precise comparison between experimental observations conducted under different conditions. Specifically, in 1979 Jon Kabat Zinn developed the eight-week intensive mindfulness meditation training program for stress reduction (Kabat-Zinn et al., 1986; Kabat Zinn, 2011), known as *Mindfulness-Based Stress Reduction* (MBSR). Subsequently, Zindel Segal, Mark Williams and John Teasdale developed a variant of the MBSR for depression prevention (Teasdale et al., 2000; Segal, Williams, and Teasdale, 2002) called *Mindfulness-Based Cognitive Therapy* (MBCT). It is interesting to note that these two standardized systems of MBIs have effects that are at least partially superimposable with those observed in the stimulation of biophilia (**Table 4**).

Biophilia constructs	**Effects of the biophilic construct**	**Mindfulness-based interventions**
Fascination	Attention Restoration (see ART)	Cognitive Therapy (MBCT)
Affiliation	Stress Recovery (see SRT)	Stress Reduction (MBSR)

Table 4. Superimposition of the effects of biophilia constructs with the effects of mindfulness-based interventions. Note how the biophilic construct of fascination acts on a cognitive function (as described by ART, Attention Restoration Theory), exactly like MBCT. While the biophilic construct of affiliation acts on an emotional function (as described by SRT, Stress Recovery Theory), exactly like the MBSR.

MBCT has effects on attention capacity (Batink et al., 2013), while MBSR works reducing stress (Goldin and Gross, 2010; Martín-Asuero and García-Banda, 2010). A research objective could be to verify whether the MBIs practiced immersed in Nature are synergistic in their restorative function. MBIs share the goal of breaking fatiguing mental patterns as described by the Attention Restoration Theory (ART). However, there is a profound difference. The process of attention restoration in Nature is passive and depends on the restorative quality of the environment. Mindfulness is active and, at least initially, requires mental fatigue.

The practice of mindfulness seeks different ways of living places, rather than looking for different places, Mindfulness practiced in natural environments could facilitate our relationship with Nature. As early as 2001 Stephen Kaplan, formulating Hypothesis 6, foreshadowed the possibility that meditation practices could

maintain the benefits of restoration even when high biophilic quality environments were not accessible (Kaplan, 2001; Clarke, Kotera and McEwan, 2021). However, it seems possible that at least some form of synergy between mindfulness and Nature (Nisbet, Zelenski, and Grandpierre , 2019; Choe, Jorgensen, and Sheffield, 2020) can contribute to activating pro-environmental behaviour (Deringer et al., 2020). If mindfulness reinforces the restorative power of Nature, then a space for *Green Mindfulness* opens. Green mindfulness could be a mindfulness practice characterized by immersion in Nature. A space of connectedness to Nature which supports and reinforces ecological awareness even when it is not possible to have direct contact with Nature. According to Marcella Danon, "Green Mindfulness [is an] expansion of one's individual boundaries towards a broader sense of sharing with the world and, in particular, with the natural world to which we belong" (Danon, 2020).

6.2 Outer environment: Biophilic Design in Architecture

An environment stimulating biophilia has restorative and anti-stress effects. Stephen R. Kellert (1943-2016) was the first to realize the importance of biophilia in architectural design. Kellert worked with E.O. Wilson on the biophilia hypothesis (Kellert and Wilson, 1993), then developed different aspects of biophilia (Kellert, 1997) before devoting himself to issues related to *Biophilic Design* (Kellert, 2006; Kellert, Heerwagen & Mador, 2008). According to Kellert "Biophilic Design is the deliberate attempt to translate an understanding of the inherent human affinity to affiliate with natural systems and processes – known as biophilia – into the design of the built environment" (Kellert, 2008, p. 3). The goal of biophilic design is to create artificial environments as similar as possible to natural ones, to ensure the positive effect that Nature has on people's health and wellbeing.

Over the past three decades, several Biophilic Design models have been proposed (Kellert, 2008; Browning, Ryan and Clancy, 2014; Sturgeon, 2017, Kellert, 2018; Browning and Ryan, 2020), which have often been implemented in advanced building certification systems (LBC, 2017; WELL, 2016a, 2016b; LEED, 2018). Guidelines derived from empirical tests and primary scientific literature have been proposed to ensure the quality of biophilic design. There are currently two guidelines for Biophilic Design that are favoured by most experts: *The 14 Patterns of Biophilic Design* by Terrapin Bright Green (Browning, Ryan and Clancy, 2014) and *The Biophilic Environment* by the International Living Future Institute (ILFI), which has created a guide for designers who want to implement biophilic design in the building certification protocol *Living Building Challenge*

(Sturgeon, 2017). Bettina Bolten and I have compared the patterns of the biophilic design described in the most relevant publications (Kellert, 2008; Browning, Ryan and Clancy, 2014; Gillis and Gatersleben, 2015; Sturgeon, 2017; Kellert, 2018) and quantified the recurrence, in order to identify the themes and models that the various authors deem fundamental for Biophilic Design (Bolten and Barbiero, 2020). The analysis was comparative and weighted. We tried to give a different weight to the patterns according to the relative importance that each Author attributed to each model. A ranking of patterns emerged, the first seven of which are listed in **Table 5**.

Kellert, 2008	**Browning *et al.*, 2014**	**Sturgeon, 2017**	**Kellert, 2018**	**Bolten and Barbiero, 2020**
Natural light	Dynamic light	Natural light	Natural light	Light
Prospect and Refuge	Prospect and Refuge	Prospect and Refuge	Prospect and Refuge	Prospect and Protection
Air	Airflow variability	Air	Air	Airflow
Views and vistas	Visual connection	Views and vistas	Views	Views
Plants	Visual connection	Plants	Plants	Greenery
Curiosity and enticement	Mystery	Curiosity and enticement	---	Curiosity
Natural materials	Nature connection with Nature	Natural materials	Materials	Natural materials

Table 5. Comparison of the most important patterns of Biophilic Design by comparing the most relevant specific studies: The last column shows my summary proposal (Bolten and Barbiero, 2020, modified).

The first four patterns – light, prospect[3] and protection, airflow, views – concern the "looking for a place to live" issue (Buss, 2016, p. 83-84) and are the basis of the savannah hypothesis (Orians, 1980; 1986). The next three patterns – greenery, curiosity, materials – are more related to the "acquisition of food" issue

[3] The 'prospect' in architecture indicates the vision of an object on a vertical plane, just like the 'plan' indicates it on a horizontal plane.

(Buss, 2016 p. 70-81). Despite their specific differences, the criteria of Biophilic Design always seem to respond to psychological needs matured during evolution. For example, by graphing the 14 patterns developed by Terrapin Bright Green (Browning, Ryan and Clancy, 2014), three clusters with at least four nodes appear clear (**Figure 4**). The first cluster, whose perimeter is outlined in green, groups five interconnected nodes which, except for the 'presence of water', appear to be linked to the safety of the shelter. The second and third clusters, whose perimeters are shown in red, each group four nodes, which appear to be linked to the search for resources and food issue.

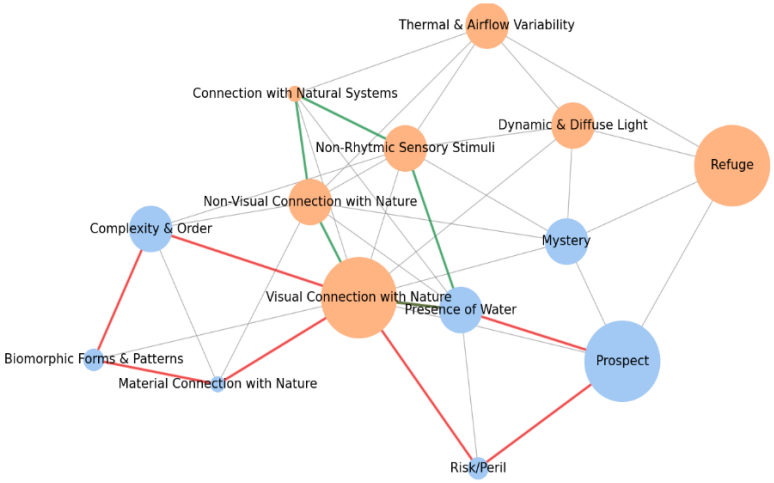

Figure 4. This image offers a visive impact of the 14 patterns of Biophilic Design by Terrapin Bright Green (Browning, Clancy, and Ryan, 2014). The graph has been generated using the Kamada-Kawai force-directed algorithm which models edges as spring forces between all pairs of vertices (Kamada and Kawai, 1989). In this graph dimensions of nodes and their connections represent respectively the robustness of the literature and the connections detected for each pattern by Browning, Clancy, and Ryan (2014). Colors of nodes: orange nodes represent 'search for refuge', blue nodes represent 'search for resources and food'. The perimeter of some of the largest 'cliques' (a subset of nodes such that every pair of nodes in the clique relates to an edge in the graph) is highlighted using a different color: green for 'search for refuge', red for 'search for resources and food' (graph courtesy provided by Pietro Barbiero).

Not surprisingly, the main characteristics of the Biophilic Design follow the evolutionary adaptation principles developed by our species in the search for a habitat rich in resources and with reliable shelters. And it is not surprising that

the top seven places in the ranking are occupied by issues more closely related to our biology, in particular the sensory apparatus, while cultural patterns (e.g., biomimicry) appear lower down, from the eighth place downwards. Instead, it is surprising that the theme of *silence* does not appear explicitly among the biophilic design models taken into consideration. I believe that silence deserves more attention, also in consideration of the experimental observations that show the importance of mindful silence in the processes of cognitive restoration (Berto and Barbiero, 2014).

In any case, one of the biggest problems of biophilic design is its empiricism, as Kellert (2018, p. 111-188) has pointed out. The projects that have been subjected to an experimental verification plan are very few. *Biosphera Project* is one among them. Biosphera Project is a research program managed by the Italian-Swiss company AktivHaus, in which Berto and I participated as Biophilic Design managers. Biosphera Project is a unique research program, because it creates prototypes of housing units that are movable. Being mobile, the housing prototypes so far made – Biosphera 2.0 and Biosphera Equilibrium – have the advantage of being able to be inserted in different urban, rural, or wild environments. Since 2016 we have been collecting numerous experimental indications that have revealed the importance of Biophilic Design, especially in the anti-stress function (Berto, Maculan and Barbiero, 2020), and which have contributed to the realization of the Biophilic Quality Index (BQI, Berto and Barbiero 2017b). The BQI then guided us in a building retrofit project of a rural school in Gressoney-La-Trinité near Monte Rosa in the Western Alps in Italy, where we integrated energy retrofit with a biophilic environment project (Barbiero et al., 2017). The Gressoney-La-Trinité school is the first school registered in Europe for the building certification protocol *Living Building Challenge* and behind which there is a systematic study of the effects that a biophilic environment can have in restoration from mental fatigue and recovery from stress, fundamental issues for primary school (Venturella and Barbiero, 2021).

7. Conclusions

In these last ten years, affective ecology has engaged above all in the experimental verification of the biophilia hypothesis. The first attempts to describe the phenomenon were the prelude to the experimental observations which led to the definition of the two fundamental constructs of biophilia: fascination and affiliation. An increasingly precise definition of the constructs permitted the use of psychometric measurement systems that allowed the psychological effects of biophilia to be estimated with ever greater precision. In this way it has been

possible to demonstrate that the fascination of Nature triggers the restoration of cognitive abilities after mental fatigue, while the feeling of affiliation for Nature has a stress-reducing effect. A biophilic environment is therefore an environment able to stimulate fascination and affiliation for Nature and constitutes the ideal environment for developing naturalistic intelligence. In the future it will be possible to define the characteristics of high biophilic quality environments, which can be both inner environments, as in the case of *Green Mindfulness* in ecopsychology, and outer environments, as in the case of *Biophilic Design* in architecture.

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Position Paper

"I simply didn't think, ok?"

Some reflections on the quality of scientific research

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Abstract. *In this paper, I explore the elusive yet crucial issue of the quality of research, taking the renowned theoretical physicist Richard Feynman as a narrative expedient. The story follows Feynman along two main episodes that mark the transition from curiosity-oriented science to big technoscientific enterprise: the Manhattan Project and the Space Shuttle Challenger disaster. Along the way, I examine the relationship between quality and truth, fitness for purpose and integrity, considering their relevance and limitations. I conclude by reflecting on quality and reflexivity in current times.*

1. Introduction

Developing tools for critical thinking, socio-ecological awareness and engagement is increasingly becoming a primary need of researchers, to better cope with the contemporary – very pressing – systemic crisis, while improving their professional and personal lives.

In the late summer of 2019, I was invited to meet and work on these issues with a group of ecology researchers of the Italian LTER network (Long Term Ecological Research), together with researchers from a variety of related fields, such as the sociology of science and technology, museology and science education, the performing arts and theater in nature, mindfulness and affective ecology.

As a means for collective reflection, I proposed a historical account of how science and technology have been defined and legitimized - i.e. demarcated[1] - over the course of the past three centuries, from the early stages of the scientific and industrial revolution to the contemporary age (pre-Covid 19, see Benessia and Funtowicz, 2016). A variety of figures ranging from scientists of different disciplines to philosophers, sociologists, public officials and entrepreneurs have been contributing to drawing an image of science and technology, by delineating its contours against the background of different socio-economic and political forces. Observing this shape-shifting image along a historical trajectory and realizing how fuzzy, permeable and contingent its boundaries are, engendered a lively discussion on the present condition of researchers. An extensive dialogue was generated about how we could better engage with the ocean of historical precedents and the current, massive socio-economic dynamics, in order to deepen the value of our research, both inside and outside our work environment.

As the days went by and different contributions enriched our collective experience, the elusive and yet crucial issue of the quality of research became more and more pressing, not only in science but also in art, as an overarching pillar of our gathering. How to generate and evaluate it, and in most cases how to retrieve it in the daily deluge of funding constraints, structural bureaucracies, and power dynamics.

[1] The demarcation of science can be defined as the philosophical drive to define what characterizes science as a form of uniquely privileged kind of knowledge, distinguishing it from all other epistemic endeavors. As an abstract analytical problem, the issue of demarcation has colonized the field of the philosophy of science for more than a century, evolving over time through a dynamical balance of ideological commitments (Ravetz 1991). As a practical problem, it can be defined as the effort to construct and maintain effective boundaries between science and non-science in the pursuit of professional goals, intellectual authority and moral autonomy (Gyerin 1983 and 1999).

During a meal in our gathering I remembered reading that the word "art" has a Sanskrit root, *"ar"*, which means: "to set in motion", "to move forward". I brought this to the attention of the group of scientists and artists I was sitting with. Some fundamental, open questions followed. What do we "set in motion" with our being in the world, as artists, scientists, policy makers – as humans? What do we value as meaningful in our research? How do we collectively foster and evaluate the quality of our creations and discoveries? These issues can be taken as a direction to navigate through the complex predicament we are facing as a species, when both science and democratic governance, the two legitimizing pillars of the quality of our knowledge and action, are faltering (Waltner-Toews *et al.*, 2021).

To explore a single path within the forest of quality, I take in what follows a selection of episodes from the work and life experience of one of the most renowned scientists of modern times, the American, Nobel laureate theoretical physicist Richard Feynman. Living between 1918 and 1988, he crossed the 20th century's technoscientific development and deployment, in all its marvels and horrors, becoming an ideal narrative expedient to reflect on the issue of quality of knowledge (science) and action (technology, decision making) over time. The story is moved forward through a set of quotes by Feynman himself, triggering different approaches to the issue of the quality of research, exploring its relationship with truth, fitness for purpose and integrity from the early 1940s to the late 1980s, a crucial time in the transition from curiosity-oriented science to big, corporate technoscientific enterprise.

Some fruitful ingredients emerge to reconsider the demands for quality of research that permeated our meeting in 2019 and are critical today.

2. Quality and truth: Feynman, Dirac and the character of physical laws

"What do I mean by understanding? Nothing deep or accurate – just to be able to see some of the qualitative consequences of the equations by some method other than solving them in detail." (Feynman, 1947)

The first episode of our story is set in the 1940s, during the Second World War. In 1942, Richard Feynman is in his twenties, a young researcher working on his PhD at Princeton, when he is asked by an older colleague, Robert Wilson, to verify the efficiency of a machine called isotron for the production of enriched uranium. Since the attack on Pearl Harbor, the Unites States are at war and the race to beat Germany in the quest for a nuclear weapon has begun.

A few months later, in 1943, Robert Oppenheimer invites the group working in Princeton to join the Manhattan Project, the American-coordinated effort for the construction of the first atomic device. Feynman manages to finish his PhD before moving to the secret military base of Los Alamos, a semi-desert location not far from Santa Fe, in New Mexico.

As one of the youngest scientists, he is assigned to several different tasks, pushing him to engage with a variety of people and types of work, far from anything he has experienced before. He essentially has to adapt his theoretical approach to the experimental needs, fast pace and multi-disciplinary environment of the Manhattan Project. He is enmeshed in the study of instruments and materials, including the so-called 'Water Boiler' a small nuclear reactor designed to experiment on the fundamental properties of chain reaction. He is dispatched to Oak Ridge, where fissionable substances are produced, to advise plant supervisors on how to handle safely nuclear waste and products. And he is in charge of the numerical calculation of implosion of the plutonium core, having to translate the abstract equations of motion into primary questions such as: How hot, how fast, how much yield?

In all these assignments, he has to communicate and work effectively with a wide range of military personnel, architects, chemical and mechanical engineers, technical personnel, and he is forced to develop a modular way of working that can be of quick and effective use to non-theorists.

In a compelling article on Feynman's work during the war, the historian of science Peter Galison describes the emergence of a specific style of research in the theoretical culture of Los Alamos (Galison, 1998). The science of neutrons, the keystone of the project, is characterized by using building-blocks, in which interchangeable pieces can snap into place, shifting the attention away from the equations of motion and moving it towards the space of solutions.

Fully embedded in the Los Alamos collective endeavor, Feynman chooses to emphasize concepts that are used to express the solutions of specific problems in visual, not formal terms, privileging plausible, not rigorous approximations. In the quantum duality between particles and fields, he favors the particulate, more intuitive, representation. He focuses his attention on the underlying physical processes, building up from the simpler to the more complex, following a bottom-up approach, rather than deducing downward from general equations.

The praxis and methodology that is needed for the mission to proceed as smoothly and quickly as possible ends up informing – and partially matching – Feynman's own character and style of research: the way in which he tackles

theoretical problems, the language he is interested in developing and his regard for physical meaning over mathematical form.

In the years from 1947 to 1949, the US National Academy of Sciences sponsors three conferences on the state of theoretical physics, at Shelter Island, Pocono and Oldstone. They are "small, closed and elitist in spirit" and they serve as rituals to cleanse and revitalize the spirit of pure research after the horrors of the war (Schweber 1986). In these conferences Feynman establishes himself as one of the leading physicists of his generation, presenting for the first time, in more and more detail, his later famous diagrams (Feynman, 1949). Part representations and part symbolic signs, the diagrams allow the visualizing and calculating of the dynamics of interactions between light and matter. They focus on elemental scattering processes, primitive pieces of a rule-governed game that can be combined *ad libitum* following some simple pictorial rules. They are built around solutions, simple expressions that "move particles" from point to point. They allow precise computations to be easily performed and they don't depend on explicit logical deductions from the fundamental equations of motions they come from[2].

This overall shift is difficult to accept for one of the initiators of quantum mechanics, the British physicist Paul Dirac. In the late 20s, Dirac formulated the equation that carries his name, as the founding stone of quantum electrodynamics (QED, the technical name for the theory of interaction between light and matter). He was awarded the Nobel Prize for his remarkable work in 1933 with Erwin Schrödinger. As one of the biggest achievements of theoretical physics, the Dirac equation of motion combined for the first time, into a strikingly synthetic and elegant form, the constraints of quantum mechanics and special relativity, describing the motion of electrons and predicting the existence of antimatter. It was the foundation of what is known as quantum field theory, the grammar of contemporary theoretical physics.

In Pocono, Dirac confronts Feynman over what he believes is a drastic departure from the search for fundamental physical laws, to favor, unapologetically, the mere setting up of working rules. Adhering to the founding spirit of Galileo and Newton, for Dirac, the quality of a physical theory has to do with its capacity to uncover the mathematical laws that govern natural phenomena, to unveil some

[2] When confronted directly, these equations presented major obstacles in the form of values diverging to infinity, precluding any physically acceptable result. At the postwar conferences, Feynman and some colleagues from his generation propose a way out of the impasse by absorbing the infinities into a few measurable, physical quantities, shifting the focus from mathematical rigor to physical meaning and quantitative computational success: a procedure named renormalization.

Truth about Nature's inner workings, through a form that appears universal and inevitable – and therefore, in Dirac's terms, beautiful. Empirical accuracy, i.e. experimental truth, is not enough[3]. If the computational rules can't be logically deduced from the equations of motion, they can't be correct.

> It is more important to have beauty in one's equations than to have them fit experiment… It seems that if one is working from the point of view of getting beauty in one's equations, and if one has really a sound insight, one is on a sure line of progress (Dirac, 1963).

Albert Einstein notably expressed this approach to the character of physical laws when he received the first experimental confirmation of his theory of gravitation, after the total solar eclipse of 1919. When asked what he would have done if the results had not confirmed his theory, he famously replied: "Well then I would have been sorry for the dear Lord, because the theory is correct" (Rosenthal-Schneider, 1919).

Leading a whole new generation of American postwar physicists, Richard Feynman is after a different kind of theory, phenomenological and intuitive, that can be routinely computed, even if that means giving up the deductive link from the synthetic universality and elegance of the primary equations of motion. Free spirited and pluralist in his style of research, he enjoys reformulating solutions to physical problems *ab initio*. In his vision, the epistemological value of a theory coincides with its capacity to make sense of physical phenomena, in a quantitative, consistent and accurate way. Its mathematical form and metaphysical implications are less relevant. In other words, the quality of his work is defined in terms of solvability[4] and empirical accuracy. Knowing how to describe and predict the interaction between light and matter in a computable and coherent way is more valuable than pursuing the mathematical, essential elegance of the fundamental laws governing it. In a parallel way to Feynman's diagrammatic theory, two other physicists – Julian Schwinger and Sin-Itiro Tomonaga – developed a formulation of QED expressed in the language of Dirac's equations of motion.

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[3] Here I use Truth, with upper case T, as a way to hint at the top-down, reductionist approach to physics, implying the existence of a single unified theory of everything (ToE) from which the mathematical laws describing all phenomena can be logically deduced. Universal truth and mathematical beauty are strictly entangled in this kind of approach. I use truth, with lower case t, as a way of referring to the empirical accuracy of a physical theory, regardless of its status and form as mathematical law. It is important to remember that Feynman fully endorsed the reductionist approach, but he wasn't attached to any specific formalism.

[4] In this sense, Feynman's style of research anticipates the characterization of science as "The Art of the Soluble" given by the British Nobel-Prized immunologist Paul Medawar two decades later (Medawar, 1967).

Even though the different versions were demonstrated to be equivalent – and earned a Nobel Prize for all three physicists in 1965 – Feynman's diagrams had the appeal of "bringing computation to the masses" (Schwinger, 1982), a different, more accessible kind of mathematical beauty.

3. Quality and fitness for purpose: thinking, knowing and the ethical box of Los Alamos

"I simply didn't think, ok?" (Feynman, 1981)

Before moving along the timeline, let's go back for a moment and look at the blind spot we left on our way, the actual success of the Manhattan project and its appalling consequences.

In May 1945, Germany surrendered and the war seemed to be close to coming to an end. Yet the work at Los Alamos continued. On July 16, the first open-field nuclear detonation, the Trinity Test, was successfully performed. At Los Alamos the event was celebrated as a great achievement. Feynman recalls beating the bongos in the back of a jeep and the general euphoria that permeated that summer night. Only Robert Wilson, the physicist who invited Feynman to work on the project since the beginning, was found moping in a room[5]. When asked why, he replied: "We did a terrible thing" (Feynman, 1975).

Less than a month later, on August 6, 1945, the uranium bomb named Little Boy was dropped on the city of Hiroshima. On August 9, Fat Man, a plutonium bomb very similar to the one tested in July, was detonated in the sky over Nagasaki. The devastating devices worked consistently well, killing instantly hundreds of thousands of people and many more over time, through radiation poisoning.

In an interview given in 1981 to the BBC, Feynman recalls the excitement after the Trinity Test. When asked about the decision to pursue the construction of the bomb even after Germany surrendered, he replies:

> What I did immorally I would say was not to remember the reason that I said I was doing it, so that when the reason changed, when Germany was defeated, not a single thought came to my mind at all about that, that

[5] In an interview given in 1965, featured in a documentary produced by Fred Freed at NBC, Robert Oppenheimer declared that he knew the world would never be the same and he famously evoked in his mind the phrase from the Bhagavad Gita "I am become Death, the destroyer of worlds". Feynman doesn't single out his reaction from the rest of the group. For the extract see: https://www.youtube.com/watch?v=_LmxIptS3cw, Retrieved on June 16, 2021.

> meant now that I had to reconsider why I was continuing to do this. I simply didn't think, ok? (Feynman, 1981).

The relationship between thinking and moral judgment evoked in Feynman's eloquent words was explored at length by the political philosopher Hannah Arendt, who fled from Germany to the United States in 1941. In 1961 Arendt was sent to Jerusalem by the journal "The New Yorker" to document first-hand the trial of the Nazi criminal Adolf Eichmann. In that experience, she was struck by his "terrifying normality", the apparent lack of any particular wickedness or pathology in his personality, other than a "perhaps extraordinary shallowness" and "a quite authentic inability to think" (Arendt, 1971). What she considered as the mere observation of a phenomenon during the trial – the *quaestio facti* famously defined as 'the banality of evil" [6] – led her to reflect in the following years on the *quaestio juris*, the right she had in defining and using the concept. In a series of illuminating lectures written in the 1970s and collected in a posthumous volume called "The Life of the Mind", she focused on the nature and function of thinking, and its relation to moral judgment (Arendt, 1971 and 1978).

> Is our ability to judge, to tell right from wrong, beautiful from ugly, dependent upon our faculty of thought? Do the inability to think and the disastrous failure of what we commonly call conscience coincide?" (Arendt, 1971)

It is difficult to imagine that Richard Feynman, one of the most capable and brilliant mind of the time, was unable to think. What happened then? Some clarifications from Arendt's writing can help us. Human intellectual abilities can be used as instruments for knowing and doing, as was so successfully the case in Los Alamos. Quite differently, the activity of thinking, in itself, as Arendt describes it, has to do with introspection. Like a powerful and uncomfortable wind, it sets knowledge in motion, unfreezes its constituting arguments, the *logoi* in Socratic terms, and leaves nothing behind. It is the movement of thinking, with no particular anchoring to any moral proposition, which creates the premises for awakening human conscience (Arendt, 1971) [7]. Conversely, lack of thinking implies a kind of stillness, in our case stiffness – a moral rigidity that didn't allow to rapidly adjust the course of actions (withdrawing from the program) according to the new available knowledge (the fact that Germany had surrendered).

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[6] Arendt's thesis on the banality of evil in the specific context of Eichmann's trial met with strong opposition and outrage, accusing her of not acknowledging the radical evil of Nazi's Final Solution, diminishing it to a narrow, formal argument (Wolfe 2011, White 2018).

[7] Arendt reminds us of the Latin etymology of the word conscience: *co-scire* "to know with and by oneself" (Arendt, 1971).

Not only Feynman, but the entire group of scientists involved in the making of the bomb reacted in the same way: they simply didn't think. How is that possible? In a lecture about his experience at Los Alamos given at the University of California, Santa Barbara in 1975, Feynman recalls:

> You see what happened to me, and what happened to the rest of us, is that we started for a good reason. Then we were working very hard to do something, and to accomplish it was a pleasure, was excitement. And you had to stop thinking, you know, you just stopped. After you thought at the beginning, you stopped thinking (Feynman, 1975).

The Manhattan Project was set up with a very precise mission: building a weapon of incomparable power, a game changer in the war. The moral reason behind the undertaking was explicit and shared: building the bomb before Germany did. The univocally defined aims and motivations were supported by a massive outlay of economic and human resources, in what is considered the first instance of technoscientific enterprise: the advent of the so-called Big Science.

In other words, building the atomic bomb was possible and desirable because it was needed. By endorsing the project, the main actors were therefore immersed not only in the theoretical culture we explored before, but also, and more radically, in an ethical box, perfectly sealed from any wind of thought, along the three orthogonal axes of competence, aspiration and duty. Inside the box, protected by the economic and military organizational machine of the project, the quality of their research (knowledge and action) was measured in terms of its fitness for the purpose of the mission. All other values – and thoughts – were externalized. The perfect detonation and the striking destructive power of the bomb were interpreted consequently, as a great success. Later, when the project was dismissed, the box broke, and a storm of thoughts awoke the conscience of most of the people involved. Feynman describes his experience in these terms:

> I sat in a restaurant in New York for example and I looked out at the buildings. How far away I was thinking, how much the radius of the Hiroshima bomb damage was and so forth… how far from here was 34th Street? …All those buildings, all smashed up and so on. And … I would go along and would see people building a bridge, or making a new road and I thought they're crazy, they just don't understand, they don't understand. Why are they making new things? It's useless (Feynman, 1975).

4. From Los Alamos to NASA

For the next episode we move forty years ahead along the timeline, to land in the middle of the 1980s at the US National Aeronautics and Space Administration (NASA). In four decades, the relationship between science, technology and society has evolved through complex and controversial dynamics, calling for a quick historical overview[8].

In 1942, in opposition to the uprising of fascist and nationalist movements, the American sociologist Robert Merton identifies the unique ability of modern science to provide "certified" knowledge as a result of the institutionalization of distinctive social norms, in the form of a specific *ethos* driving its progress. The ethical and epistemic value ensured by the so-called Mertonian norms – communalism, universalism, disinterestedness, and organized skepticism – contribute to defining the modern ideal of the "republic of science": an autonomous community of peers, self-governed through shared knowledge, ruled by no forms of authority other than knowledge itself (Merton, 1942 and 1968).

The making of the bomb marks the beginning of a new kind of modernity. The Manhattan Project essentially imports, digests and assimilates into its metabolism the epitome of Mertonian science, theoretical physics. What comes out it, besides the bomb, is the hybridization of science and technology. In this hybrid form, the quality of scientific knowledge is not determined and assessed within the boundaries of the "republic of science". It is evaluated by the larger community in charge of its technological function, deployment, and impact. New technoscientific enterprises work on an industrial scale and they require specific principles for managing and controlling the quality of their products[9].

In these early stages of hybridization, technological development is granted with the epistemic and moral legitimation of pure science. In November 1945, just after the end of the war, President Roosevelt addresses a letter to the then

[8] For or a more extensive account, see Benessia and Funtowicz, 2016.

[9] An interesting example of the industrial system of quality control comes from the American engineer and statistician W. Edwards Deming, who introduced in the 1950s the participatory practice of "quality circles" in the world of manufacturing companies. Deming's basic idea was to invite workers in assembly lines to meet regularly for sharing, analyzing and solving work-related issues. Quality circles allowed companies to benefit from the practical knowledge, experience and commitment of the workforce, while encouraging the practice of whistle blowing as an opportunity for early warnings of quality decay. Deming presented the practice of quality circles first in Japan, where he was invited to help in the post war reconstruction effort by the Union of Japanese Scientists and Engineers. His work ended up shaping the efficiency and productivity of Japanese and American industry for the years to come (Deming, 1986).

director of the Office of Research and Development, the American engineer Vannevar Bush – who played a crucial role in the establishment of the Manhattan Project. Roosevelt asks crucial questions about the role of the national government in coordinating scientific and technological development in the transition from war to peace. Bush replies by writing a later famous report, marking the birth of the US National Science Foundation, eloquently titled "Science, the Endless Frontier" (Bush, 1945). From a crucial asset of military defense, basic scientific research becomes the engine of economic growth, through its technological applications. A few years later, the shock of military nuclear technology becomes a promise of free unlimited energy, in the words of President Eisenhower's speech "Atoms for Peace" (Eisenhower, 1953).

Since the early 1960s, the marvels of technoscientific progress begin to manifest their weaknesses. Side effects and unintended consequences gain a prominent seat in the public arena and a self-conscious analysis of science as social activity becomes pressing. In 1963, the British physicist Derek de Solla Price develops the first attempt to measure the quality of scientific research with quantitative indicators (Price, 1963). In a parallel way, popular writings by a whole generation of scientists occupy two decades of civic debate, engendering the emergence of the first environmental movements and the idea of sustainable development: the marine biologist Rachel Carson and the shadows of the Green Revolution (Carson, 1962), the nuclear physicist Alvin Weinberg and the long-term risks of civil nuclear technology[10] (Weinberg, 1972), The Club of Rome and the inherent material limitations to the model of economic growth (Meadows *et al.*, 1972).

Approaching the end of the 1970s, it is painfully clear that uncertainty and complexity cannot be effectively externalized from the realm of technoscientific endeavor, as was so blatantly the case with the making of the first atomic bomb. In 1979, the nuclear accident at Three Miles Island triggers the definition of "normal accidents" by the American sociologist Charles Perrow, referring to the inevitable, built-in vulnerability to collapse of tightly coupled, highly complex technological systems, such as nuclear plants (Perrow, 1984). It is the beginning of the so-called society of risks, as defined in 1986 by German sociologist Ulrich Beck in his later renowned book, capturing the growing awareness that the goods

[10] After many years of service at The Oak Ridge National Laboratory, Weinberg points out that many of the issues arising from the side effects of technology depend on answers to questions "which can be asked of science and yet which cannot be answered by science". These questions are to be defined as trans-scientific: they come from science but quickly transcend it when attempting a response (Weinberg, 1972)

and the bads of technoscientific development are the two sides of the same coin and that risks are woven into the very fabric of technoscientific progress (Beck 1986, 1992).

Uncertainty and complexity even arise in the interplay between the individual and organizational patterns of big enterprises. Based on an extensive set of interviews to the Apollo moon scientists, the American sociologist Ian Mitroff reveals that the most revered and productive researchers at the heart of NASA are the ones that openly manifest individualism, competitiveness and explicit interest biases in their work[11]. Mitroff's work suggests, in detailed and laborious terms, that large technoscientific enterprises, characterized by hierarchical systems and high economic and political stakes, are prone to generating and rewarding a new style of research, complying with the ambivalent *ethos* of technoscientific entrepreneurship (Mitroff, 1974).

With all this in mind, we now approach the beginning of 1986. Feynman is a renowned Nobel Laureate, an admired teacher and public figure.

5. Quality, reliability and safety: the Challenger disaster

"Try playing Russian roulette that way: you pull the trigger and the gun doesn't go off, so it must be safe to pull the trigger again." (Feynman, 1986)

On Tuesday January 28, in a cold winter morning, only three months before the nuclear meltdown of Chernobyl, the NASA space Shuttle orbiter "Challenger" explodes 73 seconds after take-off, live on national TV. The seven crew members on board are killed. With them is the first civilian flying into space, the 37-year-old high school teacher Christa McAuliffe. She was selected from more than 11,000 applicants to participate in the first edition of the NASA Teacher in Space Project, a program designed by President Reagan to engage a disinterested civic society in the wonders of space exploration. Because McAuliffe is on board, the launch and the explosion are broadcasted live in many schools of America, traumatizing an entire generation of students.

A few days later, Feynman receives a call from William Graham, the head of NASA and a former student from the California Institute of Technology[12],

[11] Mitroff explicitly defines a set of counter-norms, at play in dialectical opposition to Mertonian norms: solitariness (vs. communalism), particularism (vs. universalism), interestedness (vs. disinterestedness) and organized dogmatism (vs. organized skepticism).
[12] Where Feynman taught from 1953.

inviting him to join the group in charge of finding the causes of the accident. In a matter of days, President Reagan sets up a Commission, appointing William Rogers, former Secretary of State, as chairman. Feynman is then formally hired with eleven other people. He is the only member on board who has to no ties to NASA or Washington. Not only do they have to "establish the probable causes of the accident" but also "develop recommendations for corrective and other actions based upon the findings and determinations[13]".

As the days and weeks go by, Feynman performs his task with a meticulous and unorthodox investigation, often proceeding on his own. He barely tolerates the formal meetings of the Commission, stretching the rules to privately interview the engineers involved in the program. He even submits anonymous questionnaires to the NASA personnel. As the only outsider, he works as a catalyst of information. He quickly finds out that at least one main part of the Shuttle propulsion system has a known critical issue: the pair of solid-fuel rockets that boost the orbiter at the launch and in the first few minutes of vertical flight. The boosters are made in sections by Morton Thiokol, the manufacturing company in charge of building the components for NASA. They are held together by joints, sealed by a series of rubber O-rings that need to adjust in a few milliseconds to the abrupt change in volume of the booster, when the combustion is ignited and the pressure dilates the various parts of the rockets. In a series of previous flights, the seals have exhibited an erratic behavior, sometimes presenting corrosion and blackening from hot gas burns. Official documents show that the issue has been detected as critical by the engineers, but it has not been addressed (Feynman, 1988).

It is an informal hint from another commissioner, General Donald Kutnya that leads Feynman to find the decisive piece of the puzzle. In a private conversation, the General elliptically mentions that while working on the carburetor of his car in a cold night, he wondered about the effect of temperature on the O-rings (Feynman, 1988)[14]. In the early morning of the launch, the outside temperature was 29° F (-1.6°C) and the lowest temperature of all the previous Shuttle flights was 53°F (11,6 °C). Feynman understands immediately that the issue at stake is the lack of resilience of the rubber O-ring at cold temperatures, compromising the seal and causing a fatal leak of pressurized burning fuel.

[13] From the executive order determining the work of the Commission (Feynman 1988, p.124)
[14] A different version of the story by General Kutnya can be found in "The oral history of the Space Shuttle Challenger Disaster" (Lazarus Dean, 2021).

Frustrated by the lack of speed, precision and accuracy of the assessments on the matter that he has requested from NASA, he realizes that he can test his hypothesis on his own, devising the simplest experiment: squeeze an O-ring with a C-clamp, immerse it in iced water for a few minutes, take it out, remove the C-clamp and measure the time it takes for the O-ring to get back to its original form. After a short trip to a hardware store, he carries out a test in his hotel room in Washington and it works. On the same day, February 11 1986, Feynman does the experiment again, this time live on national TV, during a public hearing of the Commission[15]. The O-ring takes a few seconds to get back to a semblance of its original shape, showing a critical lack of resilience. His memorable performance marks a decisive turn in the investigation, mesmerizing the audience, both in the room and at home. The care for the fundamental physical meaning of phenomena and the modular, bottom up approach that characterizes his style of research since Los Alamos, turn out to be crucial in his contribution as scientific advisor.

Having determined the material origin of the accident, the Commission moves on to examine the issue of causes on a different level, questioning the system of quality control in place at NASA, in charge of the reliability and safety of the machine.

Feynman examines in detail the history of the published criteria for quality certification, the Flight Readiness Reviews, only to conclude that overall system of quality control has been declining over time, becoming dangerously faulty.

The reason behind this process of deterioration can be traced in the unrealistically tight scheduling of the Shuttle flights, needed to keep the space program alive and funded. Because of the rigid time constraints, the management keeps accepting a lower standard of safety from one flight to the next, skipping obviously needed engineering revisions that would imply intolerable delays. Evident signs of faulty systems are not taken into consideration. Once again, quality of knowledge and action depend on their fitness for a purpose. It declines over time because the purpose of maximizing funding (and the chances of funding) slowly but surely takes precedence over the purpose of maximizing the reliability and safety of the vehicle. What the sociologist Mitroff has described as the inherent, ambivalent *ethos* of technoscientific enterprises such as NASA, has drastic consequences, not on the ways in which quality is defined but on its entropic dynamics. In the last episode, we explored the paradoxes of enclosing quality assessments into sealed ethical boxes, to the point of blinding the scientists involved from

[15] https://www.youtube.com/watch?v=raMmRKGkGD4

reflective thinking – and conscience. Here we observe a different kind of quality loss: a gradual decay to the point of catastrophic breakdown, resulting from the ethical friction between competing interests. From outside the box of both NASA and Washington, in this case Feynman has the room to think (about the moral fallacies of others).

6. Quality and integrity: Cargo Cult Science

"… nature can be fooled". (Feynman, 1986)

In his minority report published as Appendix F in the final assessment of the Rogers Commission[16], Feynman points out that the probabilities of failure, i.e., the risk of a fatal accident for the Challenger, are matters of "opinion" at NASA, ranging from roughly 1 in 100 in the accurate estimate of the working engineers, to 1 in 100,000 in the evaluation of the management. Such a "fantastic faith in the machinery" from the working officials is based on a flawed circular logic, in which the absence of failure in previous flights is taken as an argument for the safety of the following ones. In an article published on the New York Times in June of 1986 (Blakeslee, 1986), Feynman writes that the public officials at NASA were essentially "fooling themselves" into believing that such a "magic" way of thinking could be pursued with no consequences, because, as stated at the end of Appendix F, ultimately "nature cannot be fooled" (Feynman, 1986). Feynman refers to the "reality" of natural laws, which "cannot be fooled" by human interests, appealing to the possibility and the necessity of separating (and prioritizing) the facts of science from the values of decision-making, in the name of technological safety. As an inquisitive, curiosity-oriented commissioner in charge of a public investigation, Feynman recognizes the complexities and ambivalences of hybridized technoscience, but he still relies on the possibility of retreating within the boundaries of pure science for ensuring both the True and the Good.

The same colloquial expression that Feynman uses in communicating his findings about the Challenger – fooling and being fooled – is at the center of a commencement speech that he gave at Caltech in 1974. The subject of the talk is the demarcation of science from a specific kind of pseudo-science, which is made to have the appearance of science but is void of meaning. Feynman defines this phenomenon as Cargo Cult Science, referring to the practice of some

[16] Feynman's harsh and open critique of NASA's management system triggers strong opposition within the Commission. When asked to downplay his tone and content, he threatens to withdraw his name from the final report. As a result, his remarks are published as Personal Considerations in an autonomous appendix.

indigenous populations in Malaysia who attempted to summon the presence of military airplanes carrying goods, by mimicking the set up in which they magically appeared during the War – and disappeared after it ended (Feynman, 1974).

Young scientists are not explicitly taught but need to learn by example a special kind of integrity, so they don't fall into the traps of Cargo Cult scientific practices. This form of scientific integrity is not only honesty in the strict sense, but also the willingness of "leaning over backwards" to show that one might be wrong. This can be done only if scientists learn "not to fool themselves" in the first place, so that they don't fool other scientists and the public. "Don't fool yourself" becomes then the fundamental principle of scientific integrity and, as Feynman specifies, it requires special care because "you are the easiest person to fool". The language is different but the idea is analogous to the one expressed in the writings of Hannah Arendt. The 'special care not fool oneself' is the 'ability to think'. The fundamental components of any scientific theory, the *logoi* of research, must hold the pressure of this specific kind of wind of thought, before they can be disseminated into the world. The moral implications of not thinking, of fooling oneself into Cargo Cult scientific practices, can be disastrous.

In the public hearing of February 25 1986, the Rogers Commission collects the testimony of Robert Lund, one of the head managers at Morton Thiokol. Because NASA required a written authorization from Thiokol to confirm the launch, the company played a fundamental role in the decision that led to the catastrophe. In an exchange with Feynman, Lund keeps affirming that they authorized the launch because the role of temperature in compromising the functionality of the seals "was not clear", given that "the data were inconclusive". To which Feynman replies:

> It was clear from the point of view of the engineers. They were explaining *why* the temperature would have an effect. You see, *when you don't have any data you have to use reason*, and they were giving you reasons (Roger Commission hearing, February 25, 1986, italic mine[17]).

When facing ignorance and uncertain knowledge, the search for truth in the form of relevant statistical data has to leave room for the quest for physical meaning, coming from the active and competent reasoning of the engineers at work. The disregard for sound scientific reason in favor of an incongruous use of statistical language from the working officials can be considered as a clear instance of Cargo

[17] See https://www.youtube.com/watch?v=1jPP7Ks6Rhkandt=16973s at 5:02:56. Retrieved on 15.06.2021.

Cult practice, summoning safety by using its lexicogrammar[18]. The correspondent endemic lack of integrity, in this case of first order (moral commitment to tell the truth) and second order (moral commitment to lean over backwards with critical thinking), ends up lowering the quality of the overall system to a point of no return. The explosion of the Challenger is not an accident, but a disaster waiting to happen.

7. Quality and reflexivity: concluding remarks

Traditionally, the quality of scientific knowledge is associated with objective truth, assessed by the few who can speak its language. It is what has kept science in a unique and privileged position to legitimize action since its foundation: the modern ideal of "science speaking truth to power" (Wildasvky, 1972) and power ensuring the common good.

In our brief story, we begin by challenging this modern perspective on the quality of science from within. We have seen that, even in the deep recesses of pure science, in the search for the fundamental and universal laws governing the physical world, scientists' relationship with truth – thus quality – is not a given. What researchers consider as a valuable language and a meaningful theory depends on the theoretical cultures in which they are immersed, on their style of research[19]. As one of the founding fathers of quantum mechanics, Dirac aims at uncovering the universal mathematical laws of nature. The quality of a theory is associated with its universality, formal essentiality (beauty) and metaphysical truth. For Feynman, who learned quantum mechanics as a powerful technique to apply at Los Alamos, mathematical language is a way to understand physical phenomena, to solve problems. He is after empirical truth (Oppenheimer, 1953). This dual perspective on the quality of physical laws is very much alive and contested today. Theoretical physics is colonized for the most part by string theory, a framework that has the potential to unify general relativity and quantum mechanics[20]. Although formally and metaphysically attractive, the field of string theory does not provide clear paths to viable experimental verification. As a result, for many scientists, its epistemic quality is null, as it falls out of falsifiable – thus

[18] For a seminal work on this specific kind of Cargo Cult Science – improper use of quantitative language when facing uncertainty in decision-making processes – see Funtowicz and Ravetz "Uncertainty and quality in science for policy" (Funtowicz and Ravetz 1990).
[19] The French poet René Daumal defines style as "the imprint of what one *is* in what one *does*" (Ferrick Rosenblatt 1999, p.123). While he refers to style within artistic practice, from what we have seen, scientific research is not different in this regard.
[20] The two different theories describe the world on a very big and a very small scale. Both are accurate and yet they cannot be satisfactorily unified into a single framework.

legitimate – science (Popper ,1935). In a phrase attributed to another founding father of quantum mechanics, Wolfgang Pauli, it is "not even wrong" (Ellis 2006 and Woit, 2006).

We then proceeded to show that metaphysical truth becomes irrelevant and empirical truth insufficient as criteria for quality assurance, when curiosity-oriented science is hybridized with technological development, within big technoscientific enterprises. In this move, the quality of research shifts from the ideal of self-contained objectivity and universality – discovering the laws of nature, describing, and predicting the world of phenomena – to incorporate the realm of subjectivity. "What can be considered as a successful technoscientific enterprise, and for whom? Who can make it, how and why?" become crucial questions. In this context, quality of knowledge and action is pursued, assessed and maintained in terms of fitness for a purpose. As we have seen, this criterion carries some major limitations and pitfalls.

In the first episode, a full success in terms of technological achievement – the making of the atomic bomb – dramatically shows what happens when values are externalized and tight ethical boxes are sealed around a mission. Expressed in binary terms, inside the box, the purpose is fulfilled and the quality of the product of the technoscientific effort is at its top – it works perfectly well. As seen from outside of the box, when the mission is accomplished, it precipitates to zero. The message we can take from looking at Hannah Arendt's work is that, in order for quality to be preserved, a quest for the overall *meaning* of the purpose at stake, in the form of reasoning – of thinking as a self-reflection – has to be present in a parallel way to the intellectual search for (technoscientific) knowledge[21].

In the second chapter of our story, the friction between competing interests within the technoscientific enterprise of NASA – the safety and reliability of the technology on one side and the speed of development of the other – triggers an entropic dynamics in which quality deteriorates to the point of breakdown. Fully immersed in the ideals of modernity, as a scientific advisor, Feynman believes in the possibility of retrieving the quality of research within the boundaries of the Mertonian "republic of science", appealing to its relationship with scientific integrity: basic honesty (commitment to empirical truth) combined with the ability to "leaning over backwards" to show that one might be wrong.

[21] Arendt distinguishes between intellect, in charge of knowing (search for truth) and reason, at the service of understanding (quest for meaning) (Arendt, 1971).

In both cases, a form of critical self-reflection is invoked for the scientists at work, as an antidote to safeguard quality as fitness for purpose from its drawbacks. However, it is not clear how to procure the remedy when needed. In the first episode, Feynman states that as a scientist embedded in the mission, it was impossible to keep reasoning about the meaning of the bomb while making it: the urgency and stakes were so high that the motivations were not negotiable in anyone's conscience. In the second chapter, the retreat to the republic of science that Feynman invokes seems to be unfeasible. As many sociologists of the time were showing, lack of integrity – in the form of contending and ambivalent norms of technoscientific praxis – was not exceptional to the Challenger disaster but somehow inherent in the scale and stakes of big technoscientific endeavors (Mitroff, 1977), leading to an essential impasse in the assurance of quality over long periods of time (Merton, 1984, Beck, 1986).

What then? Some key intuitions to address the preservation of quality in the era of hybridized technoscience come from an article published in The Guardian on May 19, 1986, by Jerome Ravetz, Sally Macgill and Silvio Funtowicz, at the time working together at the University of Leeds (Ravetz *et al.*, 1986). Only one month before the publication, the nuclear disaster of Chernobyl has traumatically shown that not only the United States but also the Soviet Union cannot safely run large and complex technoscientific enterprises. In order for quality assurance to be retrieved, the authors state that not only do scientists have to commit to integrity and prudence on their own terms[22], but, most importantly, they also have to become socially and ethically *accountable*. Facing the collapse of the ideal of expert infallibility and moral autonomy[23], a new social contract of expertise has to be formed: effective public participation in technoscientific policy decisions cannot be delayed. It is the seed of post-normal science, the perspective proposed by Funtowicz and Ravetz in the early 90s to describe the inherent entanglement between facts and values in the interaction between science and policy when decisions are urgent and stakes are high, requiring the extension of participation not only as a moral commitment but as an epistemological need (Funtowicz and Ravetz, 1993).

Combining the insights from our story, the quality of research could thus be pursued and preserved over time when the aims, motivations and possible consequences of technoscientific endeavors are constantly negotiated through a form of collective reasoning (thinking as a self-reflection) – "leaning over backwards" to show how we all might be factually and/or ethically wrong. Quality

[22] Like integrity, also prudence entails a self-reflecting attitude.
[23] Defined as the Ch/Ch Syndrome (Challenger / Chernobyl) (Ravetz *et al.*, 1986).

then becomes strictly related to a form of shared reflexivity, of "self-awareness of action within a system (ecosystem)" (Funtowicz and O' Connor, 1999).

These quite abstract principles can become useful to address the demands for quality of (scientific) research that emerged in our gathering in 2019 and are most relevant in current times. Exemplifying a possible path of investigation, we could begin a process of self-reflection on our own *ethos* and *praxis* of research, by exploring the theoretical culture in which we are embedded, the methods we are accustomed to valuing, the kinds of questions we are prone to ask, our relationship with truth. Is our style of research the result of external binding conditions or is there room to express our own early inner aspirations and modes of being in the world? We could then move to investigate the aims, motivations and possible outcomes of our professional endeavours, integrating our search for knowledge with a quest for meaning. A special kind of attention could be given to the kind of language and knowledge we use. Are they adequate to answer the questions that we value as relevant? Do they need to be conversing with other kinds of language and knowledge? Most importantly: who is included in the use of "we"? Who is comprised among human beings? And who is involved among non-humans[24]?

Finally, besides mere honesty, are we willing to lean over backwards to show how we might be wrong, or simply blind? At what cost?

Asking these kinds of questions sets in motion (*ar*) a wind of thought, clearing the room for a plurality of ways of living and knowing to be explored, hopefully awaking new forms of wisdom and collective awareness.

In the writing of the American author Robert Pirsig:

> Quality is not a thing. It is an event. […] Quality is the event at which awareness of both subjects and objects is made possible (Pirsig, 1974).

As such, quality is not an asset to be found, produced or managed, but a correspondence between inner and outer world, to be summoned and nourished through persistent conscious work.

[24] For a first exploration on this crucial issue, see De Sousa Santos, 2007 and David Waltner-Toews, 2020.

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The author has declared that no competing interests exist.

Visions in Theater

TeatroNatura® in Feudozzo

Perceptive attention and bodily impulses, traditional song, and narration of an ancient myth in natural spaces as a contribution to a new sustainability culture.

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Keywords: ancient myth; embodied knowledge; performing arts, traditional polyphonic singing, transdisciplinarity.

Abstract. *This paper presents a combined educational and artistic contribution intended for a community of researchers from different disciplines interested both in ecology and in complexity. The experience we proposed highlights the lived quality of participation in a theater workshop and the encounter with the aesthetic dimension through a performance involving traditional polyphonic songs from rural cultures and oral narration of an ancient myth.*

The face-to-face exchange of resonances from different disciplines in shared knowledge building benefits the participants and becomes an integral part of the vitality of the processes that unfolded during the meeting. The underlying hypothesis is that all these aspects can regenerate contact with the senses, the body's memories, cognitive openness and flexibility, the poetic relationship with the archetypal figures that inhabit Western culture. While the centrality of scientific thought is in no way denied, the aim is to reconnect it with the mysterious and vulnerable depth from which every human desire for knowledge stems. To establish a new culture, we need to find a new way to create a successful alliance between science and artistic thinking and to open ourselves to lived wisdom, a vision of health ethics, intimately entwined with the health of the Earth.

1. Introduction: before the Cammino of Feudozzo (CaFe)

The invitation from the Italian Long-Term Ecological Research Network (LTER-Italy) for the Cammino of Feudozzo experience (CaFe) was the occasion for O Thiasos TeatroNatura® to offer a combined educational and artistic contribution intended for a community of researchers from different disciplines interested both in ecology and in complexity.

CaFe was for me an encounter like that of a karst river that flows underground for years and then emerges thanks to new favorable conditions. Each encounter was influenced by the different place in which it took place. This began around twenty years ago, thanks to the invitation by Elisabetta Falchetti, under a large oak in Centeno, between Lazio and Tuscany, at a farm owned by my family which for a while gave its name to a heterogeneous company, the "Centeno group". After this first meeting, the group launched several projects together with some of the organizers and other participants of CaFe, such as conferences at the Scientific Museum of Rome and the related publications (Falchetti and Caravita, 2005; Falchetti, 2015), and later with the University of Turin, within the Interdisciplinary Research Institute on Sustainability (IRIS). In 2016, we worked with Alice Benessia, who brought us into IRIS, at the Cantiere Immateriale (Immaterial Building Site) in her new Research Centre in Pianpicollo Selvatico in the Langhe region, through our contribution to the realization of an archive of

natural local sounds and creating a narrative performance (*Viaggio di Psiche* by Apuleius) and a concert of itinerant polyphonic songs held in that landscape (*E lu me amù. Passi cantati)*. With Giuseppe Barbiero, who we met at IRIS, we worked on some research projects involving education, theater, nature, and neuroscience, aimed at students from primary school to university[1]. Finally, the river re-emerged as part of the CaFe experience, thanks to the work of Alba L'Astorina (2018), a promoter of innovative scientific thinking, and of other research partners, both old and new.

During my first visit to Feudozzo, with my colleagues Camilla Dell'Agnola and Valentina Turrini, I already had some questions in mind, but they were still not expressed or even sufficiently conscious because, as occurs within the performative arts, where the building process alternates doing, observing, and re-doing in line with the typical procedure of theatrical workshop and rehearsals, they grow as they are stumbled on during concrete experience, with the intention of grasping and shaping the complexity of an action. Our questions were: How can TeatroNatura® contribute to transdisciplinary research on sustainability? What importance and what role do *places, bodies* and therefore also *emotions* have in knowledge? How can staying in *a place in nature* boost research on sustainability? Can *being in nature* encourage knowledge building or does it pertain only to the personal wellbeing of participants? Can immersion in nature relevantly affect the creation of a methodology and a language suitable for sustainable thinking and acting?

With these questions in mind, we built our contribution to the CaFe experience, with a workshop and a performance, to create an intimate connection between the participants and the natural location in which we were immersed.

2. The impact of theatrical performance

When working on performative art in natural spaces we have found that technological mediation (both written and digital) makes it difficult to perceive and truly encounter Nature, even when we are immersed in it. We keep on "thinking" it or "imagining" it, as for instance advertising does, drawing on our need – deep and partly removed – for real nature, but we do not know how to *feel* it anymore. We no longer know how to consciously perceive the *lived quality* of beings. Through a theatrical performance it is possible to stimulate continuity of attention towards a place and its atmosphere, giving space to new psychophysical

[1] Progetto Biofilia 2010/2011; Bambini e Natura percorso di ricerca interdisciplinare su natura vissuta e natura narrata 2014/2015

perspectives, training an imagination rooted in the present and, from here onwards, spread new visions for an awareness of the relativity of our ordinary way of seeing things (Bramini and Galli, 2007).

The contribution of TeatroNatura® to the commitment for a new culture for sustainability lies first in the rediscovered importance of theatrical practice, ephemeral but complex, which makes sense only with its audience and in the unicity of each performance. This art, when practiced in nature, without the use of recordings and digital streaming, can educate both performers and audience about uncertainty and the unexpected, awakening attention and the perception of the body, taking care of the human and environmental context, the vital experience of community, interconnectedness, and the embodied meaning of the aesthetic and ethic act in nature. In this way, it can induce a transformative process of conscience both in the performer and the audience (Bramini, 2019).

2.1. Transdisciplinarity

Other cultures, which are *closer* to the wisdom of Nature, should be listened to and integrated into our own before they disappear. We should find a transdisciplinary space and time in which to trace common fundamentals which, without surrendering to the reductionism and simplification of facile globalization, are able to connect scientific knowledge with a *wisdom* beneficial to the health of people and the planet. We should work on the permeability points of disciplinary boundaries, on the overcoming of cultural separations, thereby exploring new languages and listening to ancient ones and other cultures. Perhaps we should look for experiences and knowledge that can be shared between disciplines, above all in the context of *real life*, what the wise members of many cultures call "the art of living", and educate ourselves within a different body of knowledge, where conscience and body feed into and out of each other.

But where can Science and Art meet? According to Bateson (1971) scientists must begin to look inside the "black box" that they avoid while they follow their protocols. They must delve into that part of knowledge which is usually considered the object of study of philosophy or art, but which is still fundamental to any form of knowledge. The dark and vulnerable area between reality and the language that tries to define it probably cannot be explained. But ignoring it or thinking that it can be neglected has crucial consequences on the search for truth itself. Art is constantly listening to how that forgotten mystery still pervades life. Science is

indispensable to us but must be allied with philosophy and art to found a new human ethics committed to realizing full planetary health. Such a *health ethics* will be strictly connected to a *practice of care* based on the acceptance (not resignation) of the vulnerability of humans and all living beings (Pulcini, 2009), and will avail itself of the knowledge embodied in performing arts through their emblematic and empathic ability to speak to the present and specific context.

3. The concept of the TeatroNatura® workshop and of the performance

With Camilla Dell'Agnola and Valentina Turrini, we divided the CaFe experience into two parts: a workshop in the morning and a performance at sunset. We decided to work in the morning with the group on sensorial and perceptive aspects and to share during the afternoon, through a participative theatrical experience, a more complex and profound level of our research (Figure 1).

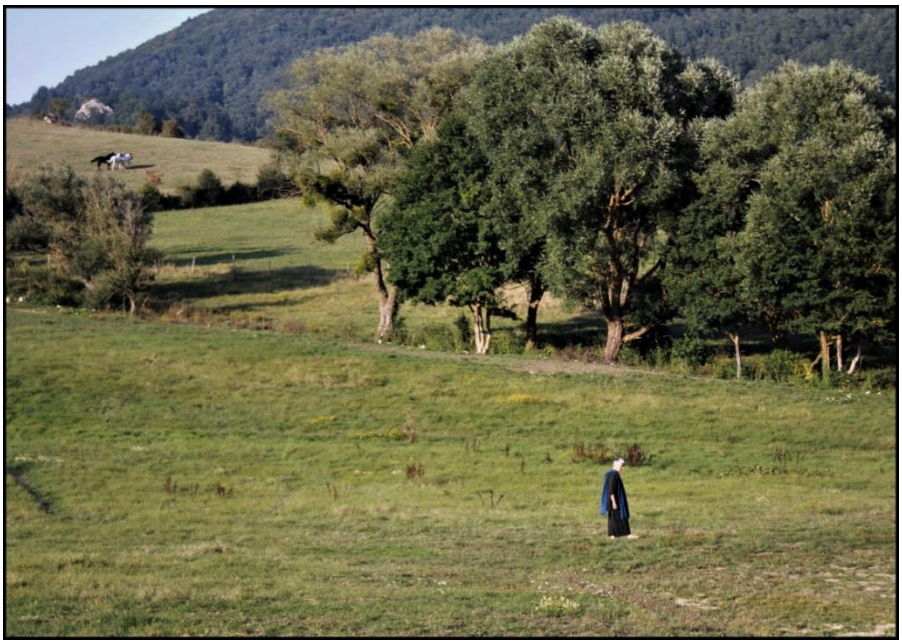

Figure 1. Sista Bramini in the setting of Foresta Demaniale Feudozzo e Azienda Sperimentale La Torre (Photo credit: Amelia De Lazzari)

We arrived one day in advance, to have time to *meet* the place, to find the right space *where* to perform, to choose *how* to create the setting and to understand which elements we could use to prepare the experience. The place is not just a pleasant or evocative container or frame for an experience. It has its own character, a particular morphological conformation, and its own acoustics. It is inhabited by living beings and provides its own atmosphere to come into contact with. The more articulate and sensitive listening to the space is, the more the creative possibilities essential for a *true encounter* are revealed.

The most common approaches to a natural place, if we exclude hiking and competitions, are intellectual and sentimental. The first, if not focused on studying the place, naming, or cataloging it, tends to relegate it to the background and consider it just as a *container* for whatever the *content* is to be and which gives value to the encounter itself. The sentimental approach *fantasizes* the place but does not *see* it, does not perceive its specific characteristics, its vital and unpredictable aspect, because it is really *imagining* a meeting with the place to derive pleasure from its narration, while truly meeting it is not. This is a cultural habit we share with our audience and our task is not related to seeing, giving, and listening to objective information, but rather to learning to forget it to be able to remain in the place with the body, its vulnerability and its impulses, its memories, and sensations, to *breathe it* (Bramini 2020). This is not easy. Thoughts keep on invading our minds, stealing our attention, blocking sensations to classify, judge, comment, even invent problems and solve them, to avoid just staying in the open air, in the uncertain, in the moment. These thought mechanisms are connected to precise psychophysical postures which we are accustomed to and that we feel as "natural". Our theatrical work starts from these cultural limitations (Bramini, 2021).

We would like us to feel free to dance, roll around, sing, breathe next to each other with our eyes closed. All these activities can be considered bizarre by those who look at us from the outside and this can influence us, so as secluded a place as possible is ideal for calmly letting ourselves go, where our triggered watchfulness could be investigative, not defensive. The words of William Blake (1988) have accompanied us from the beginning of our research and come true in a different way on every new occasion: "If the doors of perception were cleansed everything would appear to man as it is, Infinite". This perceptive relationship is not measurable, nor scientifically demonstrable, but it is profoundly real and requires precise exercise to become a part of the world that we want to learn to listen to.

3.1 The workshop

After a preparatory phase in the meeting room, the participants were invited to take off their shoes, to open up to the perception of the place, and we went outside to be on the bare ground and under the sky. We have largely lost contact with the extreme sensibility of the naked foot which, covered with sensors, knows how to communicate with the backbone, the organ of orientation which possess the ability to adapt to the conformation of natural spaces. For some people it can initially be unpleasant to take off their shoes but, after overcoming that reluctance, often thanks to the playful lightness of others, small dynamic actions, contact with the earth, gravity and balance transform the relationship with our body into motion, and encourage us to *perceive differences* and *consonances*.

Everyone is then invited to move so that each step is different from the previous one in form, amplitude and rhythm. In this way we warm up, getting out of all preconceived ideas of movement. There are smiling faces and expressions of enjoyment. Then, by making impulses leave different parts of the body, imagining them as energetic flows or beams of light, we start some imaginary "battles among shamans" with mysterious powers. In an exchange of actions and reactions we put thoughts and purposes to rest, awakening a language made of gestures that, with different energetic intensity, are rooted in an aroused body. Impulses that are not reasoned or programmed, but attentive and present and which, as if danced, go beyond the description or illustration of intentional thoughts. This is a living process that moves from preliminary phases to those in which movements are freer and "wild", not related to a "performed" simulation or a physical exemplification of concepts. Our body in motion is, as our thoughts and emotions often are, a prisoner of emotional and cultural mechanisms so that in order to be spontaneous, it is necessary to remove those habits that give us the impression of naturality, but which are merely mechanical if we look into them deeply (**Figure 2**).

Figure 2. Topic moments of the workshop organized by O Thiasos TeatroNatura® (Photo credit: Sarah Gregg)

After having awakened the body with the "battles and shamanic dances", barefoot for those who feel comfortable with it, in single file and with eyes closed, one hand on the shoulder of the person in front, we move toward the stream. With open eyes we cross the stream, jumping on the stones, and we are now on the lawn. We divide into two groups, and one explores the place with eyes closed, the while other group watches and, if necessary (although it rarely happens), protects those who move forward in the darkness. Then the groups exchange roles. The exploration of each group lasts 15 minutes, but how different the perception of time is for those who touch, smell, caress with closed eyes, and for those who keep their eyes open! Despite being in the same time and place, two different worlds are experienced (**Figure 3** and **Figure 4**).

Figure 3. Moments of the workshop organized by O Thiasos TeatroNatura® (Photo credit: Sarah Gregg)

Figure 4. Moments of the workshop organized by O Thiasos TeatroNatura® (Photo credit: Sarah Gregg)

3.2. The theater of vulnerability in the experienced place

Without a rational thematic intention, we choose as our performance *Tempeste, trilogia della rinascita* by Ovidius, which tells of three catastrophes that highlight human vulnerability as a resource. One is about the birth of democracy from the overcoming of the fear of calamities. The second shows how the individual storm of jealousy gives rise to the invention of wine as a common good. The third presents how, after a planetary catastrophe, the selfless love of an elderly couple, the only survivors, manages to regenerate all living beings from stones (**Figure 5** and **Figure 6**).

Figure 5. The performance *Tempeste, trilogia della rinascita* by Ovidius with Sista Bramini, Camilla Dell'Agnola and Valentina Turrini (O Thiasos TeatroNatura®; Photo credit: Sarah Gregg).

Figure 6. The performance Tempeste, trilogia della rinascita by Ovidius with Sista Bramini, Camilla Dell'Agnola and Valentina Turrini (O Thiasos TeatroNatura®; Photo credit: Sarah Gregg).

4. Reflections on the experience

Such workshop and theatrical performance experiences have the potential to contribute to creating, in the participants, a livelier affective relationship with that stream, that line of willows, those stones, the sunset behind the hill where the horses are. The narration and the polyphonic songs that mix with the breeze can integrate the place with the artistic experience so that it does not remain a decorative aspect. During the CaFe experience, the chance to hear the comments of the audience gave us a kind of heartfelt gratitude, as if the performance had reactivated some lost contact with the natural place and ancient myth. In this occasion, two evaluators took part actively in the workshops and performance for participant observation (Falchetti and Guida, 2021). This observation, supported by the photographic documentation by Sarah Gregg, revealed a gradual transformation of attitudes and postural changes inside the Feudozzo group, which from initial embarrassment and perplexity loosened into a sort of global and collective participation, deeply embodied and emotional, a true liberation. From the collective debates emerged that these workshops and performances impacted on communication attitudes too, undermining the usual prevailing professional expressive modes and making way also for emotions. All the participants declared they had improved their levels of pleasure and wellbeing through exploring different stimuli, narrations, and expressive languages. As the evaluators suggested, the theater performances and workshops fostered "embodied" knowledge and emotions together with dialogue with natural elements. Telling through body posture images and emotions, feeling the limits of "being scientists", had the effect of fostering in the group of "performers" new perspectives, critical concerns, and visions for more participative processes.

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Growing up with nature photography

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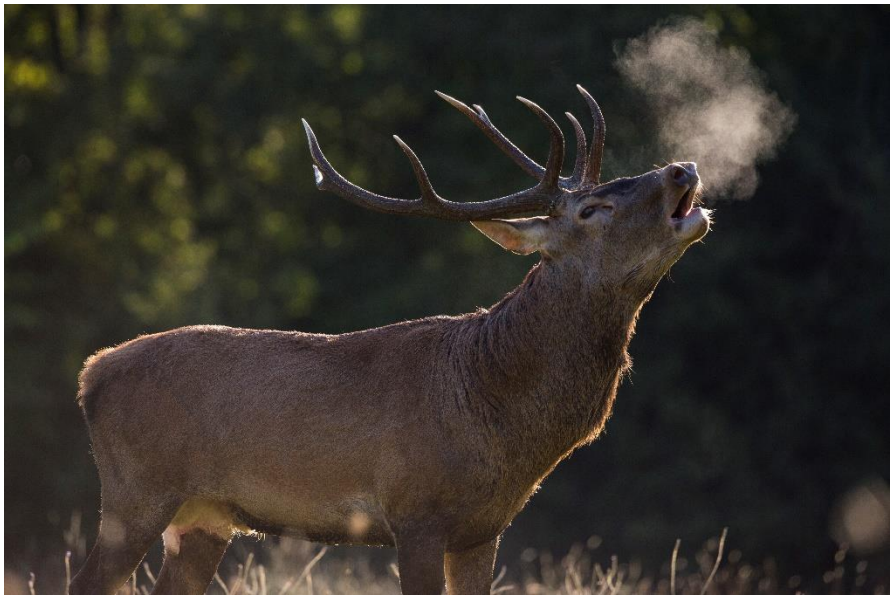
I took up nature photography at a very young age. I embarked on this path first to satisfy the need to slow down and somehow stop the constant flow of emotions and experiences lived observing animals and exploring natural environments since my childhood. The images in the pictures I took then offered me the opportunity to store those emotions forever, to relive them from time to time and to be even able to share them with others. In addition, I began to like the slow pace required by the photographic technique, which imposed patience, attention, empathy. A discipline that, compared to mere contemplation, urged me to look at things more in depth, teaching me to appreciate the constant variations of light, to look animals in the eye and to identify form and patterns in the apparent chaos that surrounds us. On the other hand, in the fleeting moment when you take a photograph, what is framed in the viewfinder becomes the most important thing in the world. This forced slowness then turned into a kind of initiation to the secrets of the subjects at the center of my photographic research. A very personal cultural journey that greatly increased my knowledge of things in nature and gradually also the sense of belonging to something greater.

With this baggage of awareness, I quickly went from a purely documentary photography to a more representative and, in some way, introspective one. What began as a moment of aesthetic contemplation soon became an inner dialogue, between the self and the world, regardless of the object or location. In fact, even portraying a small insect you notice your own image reflected in its eyes.

Once I finished my university studies and with a degree in Biological Sciences in the bag, I chose to abandon a possible scientific career and instead undertake the profession of nature photographer. This is because, compared to the rigor and the greater depth required by scientific research, photography granted me instead the freedom to span different topics, get to know very different realities and enter into a deeper communication with the subjects of my work. It was then that, to overcome the apparent superficiality of the photographic approach and to be able to build up a more robust professional portfolio, I chose to work exclusively on projects and not to seek the sensationalism of a single shot. Since then, all my photographic work has been carried out solely in the context of thorough research and meticulous planning together with a long-term approach. This allowed me eventually to turn the photo shoot into research and the subsequent sharing of images into a process of dissemination and education. In this way, I discovered the fundamental role that photography can play in the dialogue on our relationship with nature and in supporting the battle for the conservation of species and natural habitats.

On the other hand, photography is a universal and very powerful language, that allows to overcome cultural, geographical and age barriers. Images can convey messages, arouse emotions and, therefore, become an effective communication tool to increase people's awareness toward certain issues. Despite the common perception, photography is not truth but can become "true" exclusively in the intentions of the photographer. It is at the end of the path taken by the photographer, in the honesty of this person, in the ethical sense and in the empathy with which she approaches her subjects that a photographic work can become truthful. Only a respectful and sincere photograph, both regarding the well-being of the subject and the correctness of the message, can become a mirror of reality.

I chose to share this personal experience of photography with fellow scientific researchers during the seminar "In Cammino al tempo dell'ecologia" organised by the LTER network at Feudozzo in 2019, in order to possibly offer a different perspective on ecology and invite them to use photography as a tool for discovery and education.



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Reflective Visions

Mapping steps along a pathway to evaluate an experiential transdisciplinary approach to professional learning for ecological researchers

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Keywords: community of practice; evaluation; network; resonance; sustainability.

Abstract. *This paper considers some issues of debate and evaluative questions about the value, meaning and impact on the participants in an experiential pathway developed within the initiative "Cammino of Feudozzo" (CaFe), a five-day meeting which constituted a further step in a process of constant research into constructing new ways "to be a researcher" and of communicating ecology by the scientific research community. The core of this experience focused on an experiential transdisciplinary approach, designed to reinforce and develop plural, relational, and systemic perspectives, together*

with a participative observation and evaluation able to help both a collective vision and personal experience to emerge. CaFe was an opportunity for the participants to encounter different languages, narratives, ways of dialoguing, to experience multiple points of view and diverse ways of looking. Its holistic approach also involved the participants' attitudes towards social and spatial relationships. New perspectives, critical thought and visions for more participative processes were fostered by the exploration of physical and emotional experiences which revealed the limits of "being a scientist". Consequently, the evaluation pathways and strategies that were explored required new objectives, methods, and an approach to research that reflected the specificity of the CaFe experience. The evaluation focused on the participants' beliefs, disposition towards the experiences proposed and principally on changes in ideas, attitudes, interests, ways of dialoguing and communicating. This paper examines some general evaluation methods and some significant evidence of self-evaluation by the participants. All the outcomes and issues offer the chance to reflect on the doubts and perplexities of "researchers under pressure" (L'Astorina and Di Fiore, 2018) and their search for innovative models, narratives, and languages.

1. A generative approach to evaluation

In September 2019 a five-day meeting called "Cammino of Feudozzo" (CaFe) was held in the Public Forest of Feudozzo in the Italian Molise Region (for a detailed description, see L'Astorina et al., this issue). The aim was to explore possible answers and build guidelines for new ways of doing and communicating ecological research, to offer the participants an opportunity of confronting and discussing different narratives (Allen and Giampietro, 2006), multiple points of view and descriptions of the natural world, including scientific, ecological, artistic, theatrical and mythological, thereby opening transdisciplinary dialogues, promoting openness towards alternative points of view and diverse cultural domains, and seeking agreement on new ways of knowing and viewing ecology and Nature. The focus and the themes of the experience can be summarized in the following research questions: if and how scientific researchers could or should practice a

transdisciplinary vision and enrich science with other kinds of descriptions, knowledge and interpretation of the world, such as artistic-aesthetic, philosophical or mythical; if researchers could or should acknowledge and embrace different forms of narrative and expression to explore and describe Nature, to improve their communication with civil society and dialogue with non-experts; what could be the contribution of emotional approaches to creating new and more responsible attitudes towards Nature and the natural environment.

The holistic approach had the potential to impact not only knowledge and beliefs, but also personal attitudes towards social relationships and experiential ways of living. As Judith Butler (2005) suggests, such an experience takes the form of a subjective, multiple "occupation of spaces" and displacement, constituting research for ways of crossing the gap between a dominant and universal subject looking at and interpreting reality, and a contextual flow of relationships. The complex and unconventional features of the experience can stimulate debate for researchers and other potential scholars on the value of the key leading ideas that emerged and on the impact that the experiences shared had on the participants. The evaluative process described in this paper tries to draw out the strengths of the CaFe pathway and its possible short and long-term outcomes, through formal and informal evaluation procedures specifically designed for the experience.

The specificity of CaFe made it hard to imagine an evaluation process able to do justice to its innovative, interactive, participative framework, its professional self-development goals, particularly connected with relational, transversal and soft skills, its approach to social responsibility relating to science communication and public engagement, its collaborative and teamwork strategies, its call for understanding, critical and attentive thinking, its perspective of implementing new forms of research and participative choices in the participants' professional and social lives, its thematic and value-oriented horizon aiming at individual, social and environmental sustainability and an improved relationship with Nature.

The evaluation process and strategies were designed as true "field research" and as an integral part of the experimental meeting. The qualitative evaluation strategy chosen allows exploration and interpretation of different features, meanings, ideas and concepts, motivations within processes, events, and behaviors as experienced by the participants, and permits unforeseen information and data to emerge. The evaluation considers two principal research areas: the value and validity of the proposed experiences and their coherence with the CaFe goals and the impact on the participants. The approach was process-based since it focused on assessment of the participants' possible changes of ideas, attitudes, behavior,

etc., and on their personal awareness or perception of these changes. The impact evaluation, concerned with outcomes in terms of the desired changes connected with a specific experience, derives from constructivist pedagogy (Bruner, 1990; 1996) that identifies in conceptual, attitudinal, behavioral, and value changes the objectives and outcomes of professional learning experiences and processes.

The qualitative evaluation pathway developed around three main dimensions and themes: cultural (meanings, roles, perspectives, narrations, communication strategies, languages); social (collaborative team approach, social learning, community feeling, social relationships, ways of sharing experiences); personal (personal changes, emotions, visions, gaining). It involved both standardized evaluation strategies, such as brainstorming and open-ended questionnaires, together with other procedures involving more subjective interpretation of the data by the researcher, e.g., the analysis of key words and the participants' observations during some specific activities. The evaluators took part in the workshops, seminars and talks, both for reasons of personal interest and development and to conduct participant observation, a qualitative inquiry method which includes the participation of the observers inside a group activity, to analyze the context from the group members' points of view (Semi, 2010). Participant observation can explore and highlight different spheres of personal and collective experiences and allowed us to capture meaningful evaluation elements such as the appreciation, participation, the level of engagement of the participants. These multiple strategies allowed us to survey the participants' reactions in relation to the daily objectives and experiences.

Ongoing brainstorming, debates, and collective questioning, that took place at the end of every working day, allowed us to see how the active participation and the contribution of the participants to the construction of the pathway increased day by day. The brainstorming and the reflection and rethinking of one's own ideas and changes following the various experiences can be considered a highly significant feature of the pathway and key to the evaluative process. For example, the first evening meeting – during which we collectively brainstormed ideas and attitudes towards Nature, the participants' disciplinary visions, interpretation, and descriptions – demonstrated the gap between scientific interpretive models and the "essence of Nature" that many participants perceived, as well as their difficulty in searching for other knowledge opportunities beyond the usual and strongly interiorized mindsets related to disciplinary models. Further brainstorming sessions underlined the participants' gradual openness towards new awareness and sensitiveness, emotional approaches that allowed them to explore Nature in other perceptive, cognitive, and spiritual ways. This emerges

not only from the collective brainstorming sessions and conversations but also the maps of key words compiled by all the participants during the evening meetings after the daily experiences. These maps emphasized the participants' struggles and ongoing changes.

Other experiences and tasks developed to draw out hidden attitudes, emotions and potentialities of the participants provided useful elements for the evaluation process. For example, during the second day the participants were asked to collect some natural objects symbolizing their mood and expressing the key moments of their experiences. This proved highly meaningful for researchers trained to collect natural elements (faunistic, floristic, mineral specimens) following scientific-ecological approaches, and highlighted their endeavor to assume other perspectives, both in their relationships with natural objects, elements, and events and in their expressive and symbolic attitudes. Indeed, their "collections" – gathered in small plastic bags – were expressions of beauty, care, affectivity, emotional participation, creativity, and imagination, probably rarely or never expressed during their daily professional activities in Nature.

2. An attempt at evaluating the workshop impacts

CaFe involved workshop activities in the field, seminars and talks, theater performances and experiential theatrical and mindfulness workshops engaging body, mind, perceptions, and emotions. It was highly stimulating to observe the participants' "visible" reactions, to assess their levels of acceptance and participation, and the impacts of these challenging activities. Participant observation, supported by photographic documentation, revealed the gradual transformation of attitudes and postural changes inside the group, moving from initial embarrassment and perplexity to a sort of global and collective participation, deeply embodied and emotional.

From the collective evening debates, it emerged that these workshops and performances also impacted on communication attitudes, modifying usual and prevailing social and professional modes of expression based on scientific and disciplinary forms of communication, and making way for emotions. The input offered strengthened the social bond within the group by sharing together physical activities and contact. The teamwork improved through sharing stories and emotions, developing trust in the leadership of other group members while exploring one's own limits, building awareness of participating "bodily" in the experiences and with the others.

All the participants declared they had improved their levels of pleasure and wellbeing deriving from the exploration of different stimuli, narrations, and expressive languages. Such experiences, which re-connect with Nature through artistic, intense, and thoughtful practices engaging sensory-motor body systems, generate physical and mental benefits and affective resonances through free movements and foster an immersive experience expanding sensorial perceptions. Stern (2010) describes the "forms of vitality … a Gestalt that emerges from the theoretically separate experiences of movement, force, time, space and intention" (p. 5), which represent a constant and underlying lived experiences in personal life and social relationships. Movement has a primary role in creating these forms of vitality, since motor areas are actively involved in processing sensory information as well. Mirror neurons, empathy and emotions contribute to frame knowledge, concepts, and ideas (Stern, 2010). Therefore, the integration of artistic approaches and activities which can stimulate sensory-motor and emotional systems in researchers' training is beneficial, no matter what their disciplinary fields and social aims. The theatrical workshops created forms of vitality and fostered different forms of perception, through movements, contact with the earth and the theatralization of postures, fostering embodied emotions, knowledge, and dialogue with natural elements. The consequent feeling of the limits of "being scientists" had the effect of promoting in the group of "performers" new perspectives, critical concerns and visions for more participative processes.

3. Mapping the impact of the pathway through the participants' key words and comments

From the first day of the meeting all the participants were requested to express their ideas, feelings, and emotions through key words and to write them on small cards. The request was repeated in three evening briefings, to explore the participants' concept and attitude changes after the daily experiences. A semantic analysis of the key words of participants helps bring out group perceptions and feelings, creating a word cloud which favors the association of the meanings that the participants attributed to their experiences and perceptions. Looking at the word clouds enables useful elements for evaluation to emerge. The most distinctive key words can be clustered into some macro-spheres connected with emotions triggered by the various activities, metaphors and mind images, personal and collective experiences. The emotional sphere includes words like curiosity, empathy, confidence, harmony, peace, care, humbleness, pathos, intimacy, remoteness, affective closeness, fear (**Figure 1**). Following Elias et al., (1997), the strategies

aiming at discerning and managing or controlling emotions, taking care of other people, making good decisions, acting in an ethically responsible way, and developing positive social relationships, all belong to learning pathways.

Figure 1. A map connected with emotional words. Draft by E. Falchetti, M.F. Guida

The meaning of fear is noteworthy. This is a primary emotion in reaction to a danger or threat (Panksepp, 2004, 2011). The experience of novelty and originality provoked some moments of crisis in the participants. Care is also a primary emotion (Panksepp, 2004, 2011) that can be practiced as a life attitude and approach in social relationships and in professional/environmental research. It seems particularly significant that "care" was among the recurrent key words. As van Dooren (2014) argues, care emerges as a particularly profound engagement with the world, and at the same time a vital affective state, an ethical obligation, and a practical labor. As an affective state, caring is an embodied phenomenon, the product of intellectual and emotional competencies. To care is to be affected by another being/fact/situation, to be emotionally at stake with them in some way. As an ethical imperative, to care is to become subject to another, to recognize an obligation to look after another. Finally, as practical labor, caring requires more from us than abstract well wishing, it requires that we get involved in some concrete way, that we do something (wherever possible) to take care of another. In this sense, care is an entry point into a grounded form of embodied and

practical ethics (van Dooren, 2014). The awareness of the value of caring and its practice seems to have been recognized by the participants as part of researcher professional development and personality.

Empathy is another relevant emotion expressed by many participants as driving force of the pathway. Curiosity - another recurrent word - is a motivational status involving a disposition to accept new and challenging experiences. The preliminary introduction to the program probably fostered this fundamental emotion to spark an active participation. Other emotions, such as confidence and love expressed through the key words are meaningful in terms of the positive, pleasurable, intense mood of the participants. Overall, the emotional words reveal the participants' willingness to bring into play their most private and intimate personal traits, encouraged by the special involving atmosphere and by the challenging experiences, an outcome in line with an important aim of CaFe.

A second sphere concerns images and metaphors aiming at expressing and fostering the analysis of participants' professional roles and contexts: ecology, practice, pathway, crossing the boundaries, research, openness, impulse, initial drive, steps on the Earth, directness, block, intellectual barriers, restoration of perception, deep motivation, separation, complexity, fragmentation, matryoshkas, songs, drawings made by sounds and lights, movement. The participants' metaphoric language is highly evocative, rich in suggestions and powerful in creating deep connections among many dimensions of human spirit. This aspect also denotes participation, positive openness and reactiveness to the lived experiences.

The third sphere (the personal experience area) includes other evocative words: creativity, willingness, chance, patience, interpretation, space, living and observing, inside and outside, nature, thinking, bodily rooting, rebirth, breaking of enchantments, discovery. All of these are expressions of the main elements of "crisis" and rethinking of personal pathways, with an emphasis on rebirth and discovery. Finally, the most significant aspect that emerges is the value given to relationships. Their value is composed of "collaboration, kinship, sharing of future vision, profoundness of contents and relationships, friendship, membership, belonging". One key word to emphasize is "confidence", recognized by many scholars as key element of social and relational capital. Key words such as together, interconnections, connectivity, exchange, partnership, union, part of a whole, identification/empathy, people, senses, touch and to be touched, spiritual, listening, respect, prejudice and judgments, freedom, restitution, consonance, and resonance, relate to the values nourished by *communities of practice*, a dimension

further explored later in our paper. All these words point to the values that the overall experience triggered or helped recover.

What distinguishes our collective acting is the transformation from feeling part of a group of different trees to becoming a wood, a community of individuals connected by profound networks of reciprocal support (Mancuso, 2020). This distinction leads to a series of considerations on connections, interdependence, being and feeling as an interacting system. The following sentence describes very well the evolution of social relationships among the participants and their shifting towards a real community of practices and values.

A witness

Dear Friends,

Thanks for sharing these photos. To relive, re-read and see again, after several days, the emotions lived together has been for me like feeling their scent, light as a caress that warms your heart.

Thanks for all the things told, written, suggested, and sung. Thanks for those unsaid but lived. Thanks for the photos that captured the light. Thanks for the feet that, in contact with the Earth, began to walk together.

CaFe took shape around four key concepts that structured the five days of working together: Cammini, Ecology, Nature, Narration (see L'Astorina et al., 2021). However, the impact at a personal level was generated not only by these themes but mainly by the strength of the collective experience of the group. "I'm myself and I'm not alone. We can do it together". "I felt a greater self-awareness, positive energy, wishing to enter into relationship, desire for caring about the others, attention towards myself and the others". The pathway opened new visions, beliefs, ways of seeing as other participants' comments testify. "I take with me the pleasure of the shared emotions, knowledge and values during these days. I can't yet understand if and how my opinions and beliefs will change". "New ways of seeing and talking about our 'home'. I saw with new eyes, and I appreciated the difference. I discovered new horizons where I'll guide those who decide to walk with me".

The pathway impacted not only on ways of seeing, but also on the perception of others as fellow travelers, on the willingness to share emotions and to be

part of a community. "Less sense of separation from the others (especially others I don't like), less judgment, more heartfelt connection and a bit of apprehension".

The experiential value lies also in the embodied knowledge (Barbour, 2004; Gibbs, 2006; Tanaka, 2011) that is built, in recognizing the "importance of shared practices and experiences", in "being silent to be able to listen and to meditate", in "the purpose of facing present and futures challenges, feeling the collective responsibility as less of a burden", in "knowing that other colleagues will do the same".

Narrative is an expressive practice of huge communicative, ethical, and social value. Plural narrative languages – verbal, artistic (music, visual arts, theater, poetry, etc.) and bodily narrative shapes – have the power to construct or arouse dormant skills and knowledge. The workshop's narrative pathway introduced theater, photographic art, affective ecology, green mindfulness. Through the narrations built, it stimulated new unknown explorations of the relationships between human beings and Nature, with the aim of nourishing harmonious contacts and relational flows between place, self, community, and the environment.

The overall pathway offered original experiences that were recognized by the participants and organizers as playing a role in professional learning and knowledge building, and in the definition of individual and community identities. The expressive richness of the workshop constituted a powerful stimulus to rethinking one's own role, the way of planning and developing professional work and communication modes, and to searching for "an interweaving of abilities" and "peace of the soul".

One of the main goals was to find themes and relationships in different contexts (not only scientific ones) that enabled identifying transdisciplinary actions and strategies for an ecological transition. Strategies – languages, methodologies, tools – that can encompass personal, collective, and contextual transformation. Some changes at personal and collective levels emerged at the end, as participants expressed a shared sense of Nature, willingness to deepen the relations between science, communities, and societies and "the validation of values that I had inside myself and the awareness of the need and the power of creating community to turn values into a real strength".

4. A vision of the overall impact of the experience

A final evaluation phase for the overall experience was carried out by a questionnaire for the invited researchers, administered two weeks after the workshop, to

allow them to rethink their actions, memories, knowledge, perceptions, doubts and thereby build a general overview of all the experiences participated in and their possible impacts. Some questionnaires provide short answers, some other offers wider comments, but all the answers give the impression of being genuine and generous. The first results and comments obtained through the questionnaires would seem to confirm the validity of the pathway approach, its effectiveness and impact on the participants' training.

Some impacts appear very interesting in their potential for long-term effects. The impact indicators selected for the questionnaire analysis were appreciation, enjoyment, interest, knowledge and skills, attitudes, behavioral and value-based changes, together with inspiration for new visions. There was a general agreement among the participants about the value and quality of the meeting, with different reasons connected to factors like different personalities, expectations, previous experiences, and desires: "for the friendly and constructive atmosphere", "for its novelty", "for the richness of the proposals", "for the high quality of the experiences"; "for the emotional and participative approach"; "for its values going beyond expectation" "for its power to spark thoughts". All the opinions agreed on the soundness of the organization, the quality of the proposal and working styles. All the comments expressed the pleasure and enjoyment of the participants for the unforeseen human value of this meeting. Many participants described discovering that they can also feel good being together with their colleagues and during a demanding workshop, and that it is possible to open themselves to more truthful, confident, constructive, and friendly relationships. Despite their diversity, all the answers revealed a need and desire to go beyond a daily working and relationship routine that seems "flat", homologated and without passion.

The pathway seems to have set in motion or allowed to emerge several interests that were embryonic or undefined before the meeting, and which come out with great clarity and awareness. Within this cultural dimension there is a wide variety of answers focused on social themes and relationships (with colleagues, other researchers, citizens) and on the need or willingness of science communication to deal with Nature in a more intense, warm, qualitatively appealing, and less schematic way. Desires and wishes are expressed for the deepening of the newly explored techniques, methodologies, themes, that the workshop showed to be inspiring, promising, or challenging. Personal research and pathways (one's own ways of thinking, emotional quality, human and professional contacts) appear both as a need and an aspiration, stimulated by the various experiences.

The answers reveal mindful changes and acquisition of knowledge and skills related to different meanings and reasons, personal expectations, interpretations, and values. Some focused on "macro-themes" and others on details of our debate, some identified new knowledge linked to disciplinary topics and some pointed to new activities, abilities, competencies, and emotional skills. All the participants felt these were enriching and a starting point for further knowledge and achievements.

The answers also reveal changes of attitude and values regarding different expressive modes, rarely used in disciplinary and professional communication, discovering borderline experiences, overcoming disciplinary boundaries, and appreciating the work of professionals who experiment non-academic ways of knowing. All the participants felt the professional learning impetus (cognitive, sensorial, emotional, expressive, communicative, empathic) deriving from the various activities performed during the workshop and appreciated the deepness of the thoughts, the intensity of the engagement, the empowerment of the social contacts and positive relational modalities. They all believed they were more sensitive, interested, willing to experiment and, above all, keen to incorporate new values in their professional lives and personal relationships. They manifest an openness to new projects and innovation in their work, new values and strategies, new social relationships with colleagues and others. They express the desire to improve or make more effective their communication modes, to exchange and spread increasingly responsible messages about Nature and the environment, to build relations based on confidence, collaboration, and human qualities, to educate young people to the importance of these values, to encourage within their research contexts the use of alternative frameworks and practices. Many proposals emerge from the questionnaires, together with requests for deepening themes and experiences and organizing further experiences of the same kind.

5. Building and reinforcing networks as an added value of this experience

The participative and innovative design of this CaFe pathway opened new horizons and strategies able to reinforce and develop plural, relational and systemic approaches.

The impact on the network of the participants – each one a member of other networks – that met and interacted can be considered an added value of this experience. Networking provides a framework for people who interact, collaborate, share values, attitudes and approaches that guide their collective

working. The LTER network plays an important role for researchers and other professionals working with ecosystems at local, national, and international levels and the CaFe experience is one of many initiatives based on just such a networking bond. Its strength and relevance lie in the web of relations reinforced over time between the network members and the dialogue opened with other researchers, professionals, and lay people. Some elements determining the quality and relevance of a network are its continuity and life cycle, its density, in terms of the extent of the connections among the network members, its accessibility, related to the potential to get in contact with each other, the rate of connection and relations among the members, as well as the clusters that are the higher density elements of the network particularly powerful in the thoughts, meetings and debate organized by the network. In this respect, the network of researchers and professionals who conceived and carried forward the pathway showed a creative, relational, and organizing capacity able to construct a unique and involving experience for its themes and strategies, and at the same time to reinforce itself and to translate this experience in a shareable documentation and applications. CaFe enabled the LTER network nodes and clusters to increase thanks to the contacts, meetings and collaboration realized and improved the quality of the network through innovative, challenging, and thoughtful strategies and experimentation.

This networking leads to wider consideration regarding the communities of practice (Wenger, 2002) fostered by the connections between knowledge, community, learning and identity. This becomes a system of collective social learning which all the participants can access and in which each member shares the experience of the others. In this way learning is essentially an experiential and social process that promotes the negotiation of new meanings inside a community. While some approaches see learning more as an individual process, for Wenger (1998) it is a result of an active participation in community practices and of a process of identification with and belonging to the community. The LTER network creates opportunities to facilitate collective social learning and experiences, while taking account of subjectivity, personal meaning, social framework, practices, and identities. CaFe developed four fundamental levels characterizing a community of practice: practice as a social production of meanings (a common semantic), as a source of the community coherence and cohesion, as a process of continuous learning, and as a definer of boundaries. These themes stimulate many diverse thoughts and challenging visions and convictions in the process of negotiation of meanings, the commitment to the realization of common actions and enterprises, the existence of skills, tools, stories, relations characterized by an identity. The pathway involved participants in bringing new knowledge, visions, and experiences, all implying revision of the same community practices,

and offered an opportunity for all to face their own limits, boundaries, doubts, and fears through a process of sharing of emotions. This process constitutes a chance for learning, as proposed by emotional intelligence theory (Panksepp, 2004, 2011; Gardner, 1983) and by Social Emotional Learning, (Gardner, 1983; Goleman, 1995), and as described by Böhme (2010) when we enter a special mood and relationship with the different emotional tones activated by the path, the place, the relationships.

This aspect recalls the "aura" defined by Benjamin (2010) as "a sort of undetectable and pervasive influx, a distant apparition, an emotional modality generating an imaginary distance" (p. 10). "If, while resting on a summer afternoon, you follow with your eyes a mountain range on the horizon or a branch which casts its shadow over you, you experience the aura of those mountains, of that branch" (p. 10). The aura relates to the emotional distance which can be perceived starting from the emptiness which interposes itself between men and things and becomes a mind space. The landscape itself is no longer something outside us, and all of us are landscape. The pathway is based on this assumption "to create a spatial symphony" and on to come into resonance with *emotional tonalities* (Catalano, 2020, p.13). A harmonic match with the environment is achieved - as with music - by tonal chords. To conform to a certain or same tonality allows tuning or harmonizing of inner and outer worlds (Bollnow, 2009). Only within this kind of emotional atmosphere can real contact with objects, perception of things and people, and encounter with the world happen.

6. Ongoing reflections while walking

What could we learn and continue to discuss through the evaluation of the CaFe, concerning the immediate and visible outcomes and changes? What other issues can this experience trigger? The evaluation was built on our expectations, on the assessment of the experiential impact on the participants' personal and social pathways, knowledge and skills, on the possible changes in their perspectives towards more pluralistic visions, narrations, relationships with themselves, colleagues, and the environment. All of these are critical objectives and themes, worthy of debate and thoughts.

To face the limits of being a scientist seems to have given rise to new critical thinking and visions for more participative processes to become or improve a community of practice. In this sense the experience can offer indications for sharing and launching similar projects.

Le Breton (2010) states that walking means opening up to the world: "Walking plunges into an active meditation that stimulates a whole sensorial participation. We walk for any reason: for the pleasure of enjoying the time passing, to discover unknown places and faces, or just to answer the beckoning call of the route. Walking is a peaceful way to reinvent time and space. Walking requires a joyful humbleness in front of the world" (Le Breton, 2010, p. 93, translation by Ester Donnetti). CaFe was a time and a place for awareness, exchange, and discussion, thought and stimulus for change. "Being on the way and moving towards what can change". "Let's move towards change". "My way of being and walking has changed. I take home the desire to widen my community, and to think at length about my steps of yesterday and tomorrow". The change can be at the personal level, "I'm walking towards myself and my relationship with Nature", involve the richness of walking in the community, "On the way creatively and without judgment, together with this magic community", or the validation and the support in pursuing the path, "The experiences lived on these days revealed how right my walk was".

In this way, CaFe can be considered a small step towards a Responsible Research and Innovation (2020) pathway, in which sustainable goals are pursued by integrating innovative, transdisciplinary strategies into the professional learning of researchers, by improving the dialogue with different social actors and professionals, by introducing in the field of ecological research values and attitudes connected with peace, democracy, wellbeing of the planet and all its inhabitants. This within the context of a debate on researcher professional development. Along researchers' training pathways, much technical-scientific expertise is mainly promoted in university and postgraduate schools or research centers, while other transversal and affective soft skills, together with knowledge and practice of other interpretative and communicative modalities are seldom introduced. A quick glance at Internet on programs for researchers shows great attention towards technical disciplinary and managerial competencies, towards procedural skills, but low interest for interpersonal skills useful for public communication and social dialogue. Only very rarely does emotional intelligence appear among the soft skills of the researchers.

As an example, the Research Development Framework of the Edinburgh Napier University includes four domains: Domain A – Knowledge and intellectual abilities: the knowledge, intellectual abilities and techniques to do research; Domain B – Personal effectiveness: the personal qualities and approach to be an effective researcher, e.g., personal qualities development advice and examples, enthusiasm and perseverance, integrity, self-confidence, self-reflection,

researchers' responsibilities; Domain C – Research governance and organization, knowledge of the professional standards and requirements to do research; Domain D – Engagement, influence and impact: the knowledge and skills to work with others to ensure the wider impact of research. Maintaining a healthy work-life balance is also included among the researcher's abilities.

The EU Commission Directorate General for Research & Innovation (2011) published the Research profiles descriptors. These profiles include individuals doing research under supervision in industry, research institutes or universities, together with doctoral candidates. This new classification draft aims to communicate the various characteristics that researchers may have throughout their career. It describes four broad profiles that apply to all researchers, independent of where they work in the private or public sector: in companies, NGOs, research institutes, research universities or universities of applied sciences. Regardless of a particular profession, one can outline broad profiles that describe the different characteristics researchers may possess. In this description of researcher profiles, the ability of communicating with society is added only as a desirable, but not necessary, competence.

Ecological researchers should learn how to engage in social dialogue and fundamental elements of such professional leaning processes can be summarized in terms of "ecological thinking" (Morton, 2012), ecology of mind (Bateson, 2000), and critical, complex, systemic thinking (Morin 1999, 2000; Sterling, 2003; Tilbury & Wortman, 2004), all of which are essential to changing environmental relationships and policies. The researcher should know, interiorize, and practice these forms of thinking. Ecology is a scientific discipline that can greatly influence post-modern societies and is best able to promote innovative thinking and lifestyles. Ecology is vital for the way in which political, economic, cultural, social, environmental and value decisions and responsible behavior are implemented (e.g., ecological art, ecological thinking, community ecology, social ecology, ecological materials and products). Ecology is a powerful tool of integration for complex transdisciplinary narrations and has been instrumental in disseminating systemic thinking. Ecology has developed historical models for ecosystems and opened new horizons for landscape ecology, promoting acceptance of its epistemological and procedural innovations and scientific debates. Ecology has promoted the concept of sustainability, providing guidelines for worldwide scientific and political trends. Ecology can promote new awareness and ethical and social attitudes and values. Current societies have been described by scholars from many fields (and from many points of view) as far from Nature, anti-ecological, super-technological, conflicting, individualistic, subject to economics and

marketing, unsustainable, unsafe, "liquid" – by scientists (Capra, 1983; Shiva, 2005), by sociologists (Morin, 1999, 2000, 2004), by philosophers (Bauman, 2011, 2014); by religious guides (Thich Nath Han, 1993; Pope Francis, 2015), by artists such as Munch e Warhol. The responsibility of the ecological researcher goes well beyond the domain of scientific research and is connected to fundamental social-cultural planetary challenges.

What Ecology, then, and what researcher? Morin (2004) argues for a complex, interrelated dimension of the eco-socio-system as the only opportunity to redress planetary problems. The researcher should learn to understand, describe, and manage "ecologically" socio-environmental complexity and to explore alternative epistemological, philosophical, cognitive, social interpretations, narrations, and languages *of the* and *on the* environment. CaFe offers just such a perspective for developing the profile and action of the researcher.

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Competing Interests

The authors have declared that no competing interests exist.