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Exploring the potential of collaboration between geoscientists and artists for a sustainable future of the Earth

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Abstract

Over the past two decades, communication technologies have transformed the world into a global village, thereby facilitating the rapid dissemination of information. This development enables life-saving data exchanges but also alters perception, leading to a disconnection from nature and a decline in environmental awareness and conservation efforts. Engagement with digital devices detaches individuals from the natural world, highlighting the need for initiatives that promote nature-based approaches and outdoor activities to foster ecological responsibility. Some studies have highlighted that even if people are aware of ecological problems that can interfere with human health, they resist adopting virtual behaviour. This article examines the impact of communication technologies on planetary sustainability education and alienation from nature since industrialization, contributing to humanity's maladaptive environmental relationship. It also explores the potential of collaboration between geoscientists and artists to address this issue through personal experiences and interdisciplinary insights. In 2015, the Istituto Nazionale di Geofisica e Vulcanologia (INGV) proposed the first session at the European Geosciences Union (EGU) General Assembly to bring together scientists and artists.

This article retraces this journey, demonstrating how combining these two cultures can foster planetary respect and enhance the well-being of both scientists and artists.

By using narratives at INGV and geo-mythology to educate young learners, enthusiasm and curiosity about the territory they inhabit have been raised. This approach has boosted their creativity and provided a unique opportunity to increase awareness of territorial hazards while simultaneously appreciating its natural beauty.
Similarly, integrating art into scientific communities has shown significant potential for disseminating scientific knowledge to the public, emotionally engaging audiences, reconnecting people with nature, and enabling scientists and artists to critically examine issues relevant to their respective fields. Finally, the implications of geoethics are explored.

Keywords: Geoscience; Art; Planet sustainability; Geoethics; Technology

1. Introduction

In the late 1960s, the cult film "The Graduate" highlighted the impending ubiquity of plastics. During a party, Mr. McGuire (Walter Brook) advises protagonist Benjamin Braddock (Dustin Hoffman) to consider "plastics" for its future potential: "Plastics...there's a great future in plastics". This prediction is accurate but current understanding reveals that plastics pose significant sustainability issues. Persuading people to reduce consumption, despite the low cost, ease of production, availability, and omnipresence of plastic items (e.g., in electronics and automobiles), remains a challenge. Plastics dominate supermarkets. Consumers favour plastic bottles and packaging for convenience, yet inadvertently ingest plastics because of their pervasive use. Researchers have highlighted the resistance of plastics to degradation, leading to microplastics entering the human food chain, which is a growing global concern [Mamun et al., 2022; Cverenkàrovà et al., 2021].
Awareness of plastics in the food chain does not necessarily result in behavioral changes, such as recycling, which requires effort compared to the convenience of using plastic. People recognize plastics' low cost and durability, making lifestyle changes difficult within a system influenced by various factors, including a time-constrained society and a powerful plastics industry. Addressing this issue is complex. A comprehensive review of 187 studies by Heidbreder et al. [2019] found that, although individuals are acutely aware of the problems associated with plastics, they continue to value and use them extensively.

The paradoxical relationship between awareness and the continued use of environmentally harmful products extends beyond plastic pollution, highlighting one of the core challenges in addressing environmental issues. This phenomenon underscores the disconnect between knowledge and action, where individuals understand the detrimental impacts of their choices but struggle to change their behaviors. Such cognitive dissonance reflects deeply ingrained consumption patterns and the difficulty of breaking free from established habits, even in the face of mounting evidence of their negative consequences. This paradox also emphasizes broader societal and systemic barriers to environmental conservation, including economic constraints, a lack of accessible alternatives, and the pervasive influence of consumerism. Consequently, raising awareness alone is insufficient.

The issue of microplastics posing a threat to the environment and human health exemplifies the urgency of exploring novel communication and educational paradigms that extend beyond the mere transfer of knowledge aimed at raising awareness of environmental concerns. A more comprehensive approach is required that significantly motivates individuals to adopt new lifestyles and foster a sense of community belonging. This motivation should also stem from a willingness to embrace values that encourage a geoethical approach to planetary stewardship, promoting virtuous behaviours over comfortable lifestyles that are detrimental to our planet. As Peppoloni and Di Capua [2024] assert, the socio-ecological crisis is an anthropogenic crisis stemming from a crisis of the human condition. The crisis originates from the ontological perspective, lifestyle, and system of social and economic relations prevalent in the Western world, and has proliferated globally through colonialism and globalisation.

From this perspective, educational methodologies that foster interaction between artists and scientists can not only facilitate knowledge transfer but also encourage individuals to adopt an experiential approach to the planet. This approach helps rekindle a direct relationship with nature, allowing them to rediscover its beauty and one's sense of belonging.

To comprehend the rationale behind this approach, it is essential to understand the roots of our disrespectful behaviour towards the environment. It is necessary to examine how the processes of urbanisation and industrialisation, followed by a rapid technological revolution, have influenced our relationship with nature by promoting detachment from the world around us. This detachment may become further exacerbated in the immediate future if we do not reestablish an emotional connection with nature. In this context, art can make a significant contribution.

Environmental challenges, including water contamination, biodiversity threats, unsustainable food systems, and fossil fuel dependence require immediate collaborative action. Addressing these issues requires scientific research,

humanities support, policy involvement, and individual efforts. Scientific advances must be translated into environmentally responsible public behaviour, necessitating an approach that integrates scientific knowledge with social, personal, and environmental factors and emphasises cross-disciplinary collaboration and environmental awareness. Science communication has evolved into a "social conversation around science", valuing quality over impact and effectiveness [Bucchi and Trench, 2021]. Its philosophical basis connects researchers to society, languages, and culture. Despite integration into scientific institutions, much science communication remains in "shadowlands", lacking visibility and understanding [Gani et al., 2024]. Poor organisation in academic practice highlights the need for a systematic methodology to bridge the gaps between established protocols and public outreach. This interaction between science, communication, and society requires a structured, transparent approach to connect disciplines and illuminate overlooked aspects of scientific discourse.

Problem-solving can be achieved through a transdisciplinary approach, initially coined in academia but increasingly relevant to innovators and entrepreneurs addressing complex societal issues. Transdisciplinary innovation is characterised as being action-oriented, future-focused, participatory, holistic, systemic, purposive, and transcending individual disciplines and practices [Jantsch, 1972; Thompson Klein, 2002; Polk, 2014; McPhee et al., 2018]. Unlike multidisciplinary and interdisciplinary approaches, it is not merely about working towards a shared goal or having disciplines interact with and enrich each other.

Transdisciplinarity is the most advanced approach to complex systems, with multidisciplinarity and interdisciplinarity at intermediate stages. Over the past two decades, at INGV, the author's humanities background has supported interdisciplinary collaboration and the exploration of new communication formats, such as narrative, science theatre, and geo-mythology. Utilizing insights from neurosciences, eco-psychology, and art-based methodologies, the author's educational approach fosters respect for the planet through managing virtual world time, distinguishing between virtual and real worlds, emotional engagement via creativity and art, student involvement in nature projects, and a sensory-based approach.

This article explores the complex interplay between communication technologies, environmental education, and humanity's relationship with nature in the context of planetary sustainability. It examines how modern communication tools have transformed the ways individuals learn about and engage with environmental issues, potentially bridging the gap between people and the natural world. However, it also addresses the paradox that, while these technologies can raise awareness, they may simultaneously foster a sense of disconnection from nature.

Moreover, it further explores the historical roots of humanity's estrangement from the environment, tracing this shift back to the Industrial Revolution. This period marked a change in how humans interacted with and perceived nature, often viewing it as a resource to be exploited rather than a system to be preserved. I argue that this alienation has led to maladaptive behaviors and attitudes toward the environment, hindering efforts to address pressing ecological challenges.

Finally, strategies for cultivating a sustainable relationship between humanity and nature are discussed. Despite limited research on the effectiveness of art-science collaboration in promoting behavioral change, some studies suggest its potential in advancing planetary sustainability [Cardenas and Rodegher, 2020; Trott et al., 2020; Heinrich and Kørnøv, 2021]. Therefore, I explore the interdisciplinary collaboration between scientists and artists, drawing on examples from INGV's initiatives at the EGU General Assembly, to illustrate how merging diverse perspectives can foster innovation and deepen our understanding of planetary complexities. The discussion highlights the mutual benefits of scientific research and artistic expression, emphasizing the inspiration and growth that can emerge from bridging these fields. This approach could offer new perspectives on environmental challenges and natural disasters, enhance the communication of complex geological concepts to the public, and inspire novel research and creative solutions for environmental issues, ultimately contributing to a holistic understanding of planetary dynamics.

I believe that my considerations can be significant from a geoethical perspective in several ways, in particular on the importance to: adopt a multidisciplinary approach that integrates communication technologies, environmental education, and human-nature interactions; scrutiny the ethical considerations surrounding the use of technology in environmental education; conduct a historical examination of human-nature relationships from the Industrial Revolution onwards; concentrate on the impact of natural alienation on environmental conduct; underscore the importance of global sustainability; offer valuable insights for geoethical training and outreach programmes; assess the influence of technology on shaping environmental attitudes; aim to re-establish the connection between humans and nature; and investigate strategies to bridge the gap between people and the natural world.

2. The impact of modern technologies on educating individuals

In March 2024, following an extensive period of deliberation, the International Union of Geological Sciences (IUGS) ratified the decision not to include the

Anthropocene as a geological epoch [Koster et al., 2024]. In parallel to this, a novel concept has emerged. Two evolutionary biologists propose the utilisation of the term "Technocene" for the current geological epoch. Their rationale, in their own words, is that "what the Technocene idea makes clear is that, as modern human societies exhibit an enormous coupling with technology and for the first time in human history that technology has the potential to modify the very core processes that drive Earth System dynamics, then Technology must be considered as a new dimension of analysis in the study of Earth system in its coevolution with life and particularly human beings" [López-Corona and Magallanes-Guijón 2020]. The Technocene concept emphasises the profound influence of technology on Earth's systems and human society, extending beyond anthropogenic focus. This highlights how technological advancements intertwine with natural processes, potentially altering planetary evolution. This perspective offers a new lens to examine the interactions between human innovation, ecological changes, and global systems, reshaping our understanding of our role in shaping the planet's future.

As Peppoloni and Di Capua [2024] assert, science and its technological products are efficacious instruments for addressing crises. However, to contribute transparently and responsibly to a more cognisant and equitable society, it is imperative to consider potential adverse consequences of scientific and technological development. Scientists must provide society with objective elements for decision-making, whilst exchanging information and stimulating discourse within their professional community on ethical, social, and cultural issues related to their activities. This encompasses reflecting on responsibilities inherent in their roles, as well as on the concept of public good and respect for ecosystems.

It is undeniable that modern technologies have brought significant benefits. They have revolutionised our global capacity for connection, idea exchange, and interdisciplinary collaboration, thus yielding significant outcomes. For example, computer systems enable immediate earthquake localisation and early warning systems that save lives during floods. Ongoing research seeks the most effective ways to disseminate timely information to the public [Budimir et al., 2020]. Most information these days is disseminated through the internet and this inevitably leds to the downside: the growing prevalence of Internet usage affects cognitive systems and social life, with effects that are not always positive.

Individuals engage in daily digital platforms, reaching millions of people globally. The rise of smartphones and social media has allowed people to access the digital world anywhere and instantly. Human attention is distracted by vast amounts of information, prompting professionals to find new ways to capture it. Marketing experts describe "content shock" as a phenomenon in which online content loses

visibility because of oversupply. Continuous innovation in attention-capturing methods is necessary as the attention span decreases. The brain experiences stress from information overload, making sustained concentration challenging.

The pertinent statistics on global population and media usage, alongside data on government, economics, environment, food, water, energy, and health relevant to this study are avaible online[1]. Notably, the current number of Internet users is approximately 6,518,000,000, which nearly matches the global population (8,203,721,074). At first glance, comparing the number of cars produced with the number of bicycles and computers reveals how dominant the internet has become in our daily lives. Similarly, if we compare the number of published books with the sales of cell phones and video games, the contrast is striking. Enormous numbers are associated with all the activities we carry out daily on the web. The Internet has emerged as the most widespread and rapidly adopted technology in history. Consequently, neuroscientists are currently examining the impact of digital technologies on cognitive abilities. A major discovery in brain research is its adaptability to environmental demands and stimuli, particularly in acquiring new processes owing to neuroplasticity [Draganski et al., 2004, as cited in Firth et al., 2019]. Long-term effects of digital technologies on cognitive abilities remain uncertain, necessitating further research. Draganski et al. [2004] suggest that Internet use may differentially impact cognitive and social functioning based on developmental stage. Digital natives, the first adopters of new online technologies, comprise 95 percent of U.S. adolescents with smartphones, 45 percent of whom are nearly always online [Anderson and Jiang, 2018]. Educational institutions have observed negative effects on children's attention, with 85 percent of teachers concurring that digital technologies create a readily distracted generation [Purcell et al., 2012]. The extensive use of the Internet and social media significantly affects social life and disrupts mental and physical well-being, thus impacting social relations [Firth et al., 2019] and our connection with nature. Pervasive digital immersion in modern society has profound effects, especially on the younger generation.

Technological saturation influences children's cognitive development, educational experience, social interactions, and interpersonal relationships. Constant exposure to digital devices and virtual environments shapes how children learn, process information, and communicate, potentially hindering face-to-face interactions and development of crucial social skills.

Moreover, this digital omnipresence extends beyond individual development and affects collective relationships with the natural world [Kesebir and Kesebir, 2017]. As an increasing amount of time is spent in virtual environments, there is a growing

[1] See https://www.worldometers.info/ (accessed 3 February 2025)

disconnection from the physical environment, potentially leading to diminished appreciation for nature and its significance. This shift raises critical questions regarding the long-term implications of our increasing dependence on technology and its impact on environmental awareness and conservation efforts.

The challenge is to balance technological advancements while maintaining a meaningful connection to the natural world. To this respect, Peppoloni and Di Capua [2023] assert that *Homo sapiens* has accelerated the process of continuous adaptation, causing anthropogenic changes in the Earth system to occur at a significantly higher rate than human adaptations to changing external environmental conditions. Consequently, humanity may no longer possess the capacity to adapt to the environmental alterations it has induced, potentially entering a perilous biocidal cycle.

As we innovate and integrate digital technologies into our lives, it is crucial to consider their potential impacts on ecological consciousness and our ability to address environmental issues. This dichotomy between technological progress and environmental stewardship requires careful consideration and proactive measures to ensure harmonious coexistence between digital advancement and our connection to nature.

3. Alienation from Nature

In 1992, Theodore Roszak (1933-2011), a Stanford University History Professor, introduced "eco-psychology" in his book *The Voice of the Earth* [Roszak, 1993]. This field seeks to enhance the emotional connection between individuals and nature, promote sustainable lifestyles, and address the phenomenon of alienation from nature. In an interview, Roszak suggested that future discussions on mental health would inevitably involve an individual's relationship with the environment. Human alienation from nature became evident in the late 18th century, when Rousseau [1762] advocated for rural child-rearing. Konrad Lorentz (1903-1989) later used "alienation from nature" to describe a growing tendency for people to interact more with artificial objects than with plants or animals [Lorentz, 1974 cited in Jančaříková et al., 2020].

Alienation from nature, initially caused by urbanisation and industrialisation, has been further intensified by digital technologies. This phenomenon has been widely examined, with some studies identifying it as a major challenge for sustainable development. El-Kamel Bakari [2014] discussed how neo-capitalism and globalization have deepened the man-nature divide through "time-space distanciation." He states: "While revolutionary in fields like telecommunications, this

feature has significantly hindered efforts to bridge the man-nature gap and promote sustainable development. By fostering an unrealistic society-environment relationship, 'time-space distanciation' obscures the direct link between wealth accumulation and environmental degradation, increasing contemporary post-industrial societies' estrangement from nature. Accelerated by economic globalization, 'time-space distanciation' has also weakened public awareness strategies."

Jančaříková et al. [2020] highlight that children's attitudes towards nature are shifting, with increased fear and aversion towards animals and sometimes plants, coupled with reduced interaction with the natural environment. Exemplary practices exist that reconnect children with nature. This trend may be linked to the estrangement of nature experienced by the parents and teachers. To promote planetary sustainability and instill respect for nature, we must address this alienation and reinforce community and kinship with all living organisms. Reclaiming our ancestral belonging to the planet involves reigniting our appreciation of natural beauty. A holistic approach integrating environmental education, community engagement, and renewed appreciation for an interconnected life is essential. This strategy recognises that addressing environmental challenges requires a societal shift in values and behaviours, not just scientific knowledge. Environmental education is crucial for fostering ecological literacy and empowering informed decisions regarding planetary impacts. Integrating sustainability into curricula at all educational levels can nurture environmentally conscious citizens [Lugg, 2007].

Moreover, by combining scientific knowledge with artistic expression, passionate engagement, and emotional intelligence, we can create a holistic and impactful approach to environmental education that resonates with diverse learners.

4. Science, Art, passion and emotional intelligence

Historically, human civilisation has relied heavily on natural phenomena. Celestial bodies guided navigation, and the sun regulated daily rhythms and symbolised life. Maritime travel was the only way to reach the uncharted territories. Natural elements were revered and worshipped for survival. Artists have also long found inspiration in nature. For instance, ancient Egyptian culture used animals as power symbols in funerary art and sculptures. Currently, artists use plastic debris from coastlines to highlight oceanic pollution. In 2018, a 10-meter whale sculpture made from 250 kg of plastic bottles was displayed at Rome's National Geographic Science Festival. Named Plasticus, part of the Sky Ocean Rescue Initiative,

symbolises the amount of plastic waste entering the ocean every second. Such installations underscore urgent environmental issues and the unsustainable relationship between humanity and nature. Modern society has diminished the sanctity of nature, fostering the illusion of independence from natural systems.
Encouraging a sustainable lifestyle necessitates individual commitment and effort, as well as robust public motivation. As previously discussed in the introduction, there exists a disconnection between knowledge and action, wherein individuals comprehend the detrimental impacts of their choices yet struggle to modify their behaviours. The incorporation of emotional intelligence may help address this issue. As defined by Mayer et al. [2008]: "emotional intelligence involves the ability to carry out accurate reasoning about emotions and the ability to use emotions and emotional knowledge to enhance thought." Art has consistently demonstrated the capacity to evoke emotions and passion, potentially influencing behavioural change, even within a short timeframe. Consequently, science and technology alone have been insufficient [Shrivastava et al., 2012]. Collaboration between scientists and artists has considerable potential to foster a culture of sustainability by appealing to both rational understanding and emotional connections.
Figure 1 illustrates the initial phase of this partnership with art, which plays a significant role in facilitating the transfer of knowledge based on complex issues by scientists. It is, however, crucial to emphasise that this collaborative approach extends beyond traditional scientific communication, offering a unique platform for engaging diverse audiences and fostering a deeper appreciation for Earth sciences. Through the incorporation of artistic elements, scientists can create more immersive and emotionally resonant experiences that enable the public to connect with complex geological concepts on a personal level. Moreover, this interdisciplinary approach may lead to innovative research methodologies and creative problem-solving techniques, potentially revealing new avenues to address pressing environmental challenges.Cardenas and Rodgher [2020] report that successful art science collaborations lead to improved communication skills, better problem articulation, more creative problem solving and questioning of personal and disciplinary mental models. Trott et al. [2020] highlight that art-science integration facilitates transdisciplinary learning, participatory processes, and collaborative sustainability action. Heinrich and Kørnøv [2021] reported a successful workshop that combined art-based approaches with sustainability science, resulting in solutions that neither discipline could achieve independently. The emergence of concepts such as "knowledge expansion," "complementary," and "disciplinary self-reflection" from this study underscores the unique value of art-science collaboration to sustainability efforts.

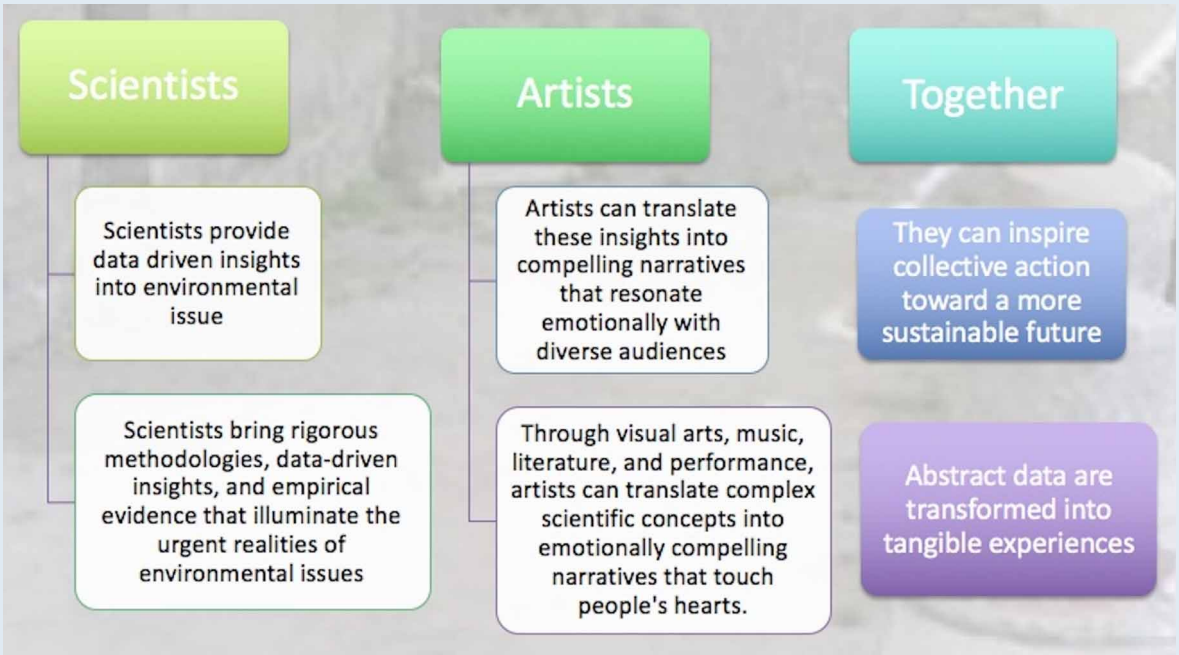

Figure 1. *The basis of artists and scientists partnership.*

Educators and science communicators can leverage the collaboration between scientists and artists. Activities at this intersection not only attract public interest, but also enhance the awareness of individuals' relationships with the planet. Through recreational or emotionally impactful activities, the initial critical step involves reflecting on behaviours, potentially influencing them, even in the short term. However, we must prioritise evaluation activities. Despite extensive experience at conferences dedicated to the convergence of geoscientists and artists, evaluation and impact have not yet become central concerns. Given the interdisciplinary nature of these collaborations, encompassing diverse approaches to reality, it is essential to consider appropriate evaluation methods, recognising that the arts also involve an aesthetic experience [Muller et al., 2020].

Interdisciplinary partnerships between science and art require sophisticated and multifaceted assessment approaches. This approach must balance scientific rigor with artistic sensibility, recognising that each discipline offers valuable perspectives. The evaluation framework should be flexible to accommodate various methodologies and outputs from these collaborations, while maintaining high standards of quality and innovation. Developing new metrics may be

necessary to capture the synergistic effects of combining scientific enquiry with artistic expressions. Traditional scientific impact measures, such as peer-reviewed publications or quantitative data analysis, may need to be complemented by qualitative assessments that appreciate the aesthetic, emotional, or communicative aspects of art. Similarly, artistic criteria may need to be expanded to consider scientific accuracy, methodological soundness, or real-world applications whenever claims to deal or it is based on scientific concepts.

The assessment should also acknowledge that the value of interdisciplinary collaboration often extends beyond immediate outputs. The cross-pollination of ideas, methodologies, and perspectives can lead to unexpected innovations, foster creativity in both fields, and potentially open new areas of enquiry. Evaluators must be open to recognising novel forms of impact and contributions beyond conventional success measures.

Ultimately, this nuanced assessment approach aims to foster genuine collaboration between scientists and artists by acknowledging and valuing the unique strengths of each discipline and recognising the emergent properties of their interactions. This can lead to a more holistic and transformative approach to knowledge creation and problem solving in our interconnected world.

In 2004, the 32nd International Congress of Geology (IGC) provided me with the opportunity to participate in a session devoted to geomythology. The discipline was first described by Dorothy Vitaliano, an American geologist who, in *Legends of the Earth*, synthesized geological research with the study of local mythology [Vitaliano, 1973]. Vitaliano coined the term "geo-mythology," positing it as the application in geology of "evemerism," derived from the Sicilian philosopher Evemero da Messina (300 BC-250 BC), who postulated that mythological deities were deified mortals. Consequently, geo-mythology can be understood as a discipline predicated on the premise that certain myths and legends may be elucidated as geological events observed by diverse populations. Geomythology exemplifies an interdisciplinary field that bridges the geological sciences and humanities. Myths have consistently held significant importance for humanists. This discipline afforded me the opportunity to collaborate with colleagues from the earth sciences and other disciplines in the field of science narrative.

5. Science Narrative at INGV

The potential of utilizing narrative, including geo-myths, as a valid instrument for science communication and education has been extensively investigated [Lanza and Negrete, 2007; Negrete, 2009; Negrete and Lartigue, 2010; Negrete, 2021]. Specifically, geomyths can be employed in educational settings to capture student attention and stimulate discourse on how contemporary science elucidates phenomena that myths attempt to explain without scientific knowledge. Additionally, they can enhance interest in and awareness of the local environment, facilitate reconnection with nature, and promote geoethics. Geo-myths have been utilised in various artistic approaches, enabling the exploration of the potential of science theatres, open-air museums, and narratives for younger audiences [Lanza et al., 2013; Lanza, 2014; Lanza and D'Addezio, 2021]. These geo-myth projects have not only engaged students but have also fostered a deeper understanding of geological concepts through creative expression. Diverse artistic approaches have allowed for multisensory learning experiences, making complex scientific ideas more accessible and memorable for young learners. By combining science with storytelling and visual arts, these initiatives have successfully bridged the gap between academic knowledge and cultural heritage, thereby creating a unique educational framework. In other words geomyths foster creativity. Several studies have suggested that engaging pupils in outdoor environments for a portion of their school time can enhance their creative development [Davies et al., 2012]. Geomyths have provided this opportunity.

All the projects incorporated outdoor activities and were conducted outside the classroom environment. In the initial experiment, a science theatre experiment, conducted with students of a primary school [Lanza et al., 2014], the majority of activities occurred in a school theatre, generating a secondary outcome that involved not only the teachers but also the children's parents. Creative endeavours, such as modifications to the show's script, development of costumes, and introduction of new characters to accommodate the enthusiasm of all participating children, demonstrate that knowledge of natural hazards (such as earthquakes) can be effectively transmitted by eliciting emotions distinct from fear. The experience has also shown the power of theatre to create a strong atmosphere of collaboration, instilling enthusiasm.

The second project [Lanza, 2014] involved secondary school students in an open-air museum experience, with the objective of elucidating the territory to visitors during the European Day of Parks at the final event of Nemi Lake, near Rome (Italy). Throughout the project, students were immersed in the natural environment of Castelli Romani Park with the aim of identifying an itinerary to elucidate the history,

mythology, and geology of the area through scenic representation. The experiential learning approach implemented in this context not only enhanced students' comprehension of natural hazards and local geography, but also cultivated creativity, collaborative skills, and community involvement. Theatrical production and open-air museum experiences exemplify innovative pedagogical methods that transcend traditional classroom instruction, enabling students to actively engage in and contribute to their own knowledge acquisition process. These initiatives demonstrate the potential to integrate artistic expression, scientific concepts, and cultural heritage in educational settings, thereby creating enduring and impactful learning experiences for students across diverse age groups. Ultimately, the open-air museum initiative proved to be an effective means of integrating various curricula, while providing a valuable opportunity to enhance the understanding of the Lake Nemi region.

The third phase of experimenting with geo-myths involved secondary school students engaged in readapting myths and transforming them into fairy-tales for primary school children [Lanza and D'Addezio, 2021]. This approach provided an opportunity to utilise geo-myths in a novel manner, enabling students to initiate their engagement with creative writing for educational purposes in the context of younger learners. The primary objective of the project was to introduce children to their local territory and enhance their awareness of environmental issues. The identification of myths associated with the territory in an area characterised by abundant vegetation, shaped by intense volcanic activity over hundreds of thousands of years and subject to frequent, albeit moderate, seismic activity, such as that of Castelli Romani (in an area near the southern part of Rome), enabled the students to comprehensively explore the territory. Finally, they interacted with primary school children during public events, organised both at the INGV headquarters in Rome and at the Geosciences Museum in Rocca di Papa. The initial approach to creative writing emerged spontaneously during secondary school students' experiences (see Figure 2). The project's scope extended beyond its initial target demographic, engendering a cascading effect on learning and engagement across diverse educational strata. This unanticipated outcome underscores the potential of intergenerational learning experiences in science communication. Figure 2 summarizes ten years of projects with primary and secondary schools and their outcomes.

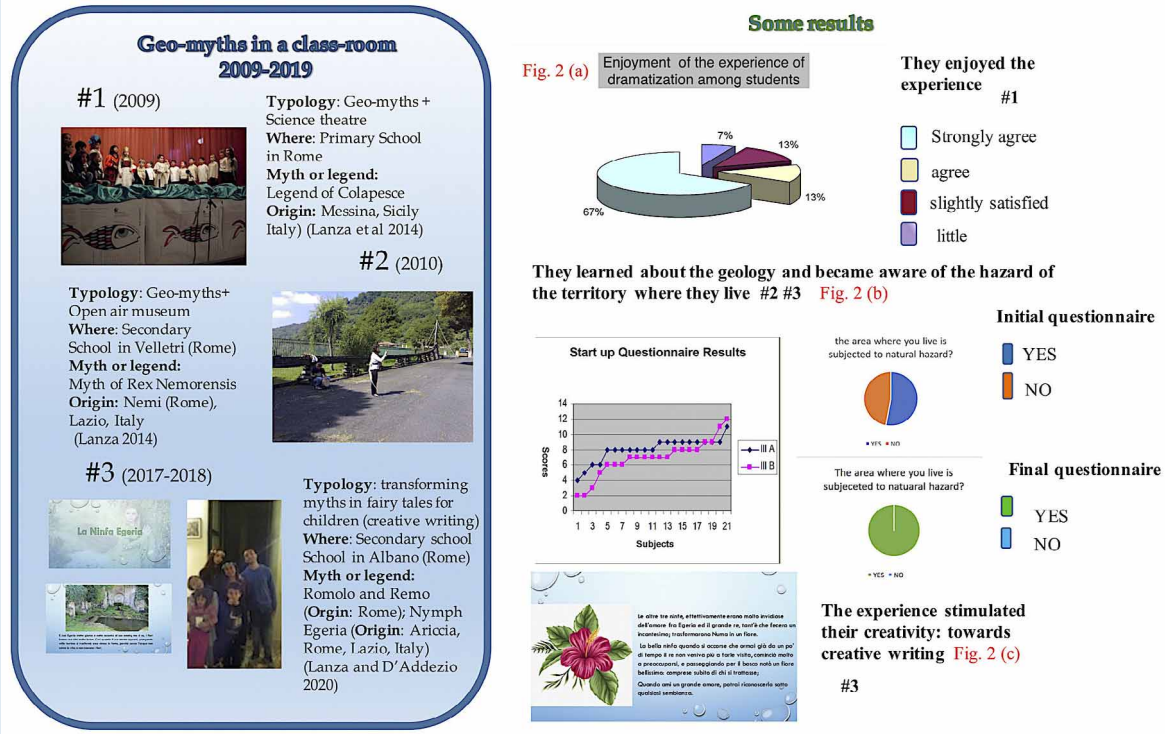

Figure 2. *How we used geo-myths and some results [Lanza, 2020]. On the left, we utilised geomyths in conjunction with various educational formats (theatre, open air museum, and fairy tales). Some of the results are shown on the right-hand side: 2(a) illustrates that students particularly appreciated the experience of science theatre. The light blue section represents the percentage of students who valued their experiences definitively (#1); 2(b) on the left: A start-up questionnaire administered after the training activity of group A (experimental group) and group B (control group) demonstrated that prior knowledge of the Nemi Lake area was limited, and the project served as a valuable and exclusive means to acquire such knowledge (#2) [La Longa et al., 2013]; on the right: an examination of a specific item from the initial questionnaire juxtaposed with the concluding assessment demonstrated that marginally over 50% of the students recognised their locality's vulnerability to natural hazards. Engagement in the project addressed this knowledge gap (#3) [Lanza et al., 2018]; 2(c) illustrates a slide crafted by students to convey the myth of Ninfa Egeria as a fairy tale to primary school pupils. In their adaptation of the myth, the students employed the imagery of a flower to address the notion of mortality in a more subtle manner (#3) [Lanza and D'Addezio, 2021]. The major difficulty students encountered was that they found it difficult to trace back the links between ancient myths and the geology of the area (#1#2#3).*

6. Earth sciences and art sessions at EGU

The first Earth sciences and art sessions at the EGU General Assembly were proposed in 2015. The introduction of art into the broader community of geoscientists in Europe was initially successful. The session continued until 2019

and garnered contributions from several European countries and beyond, including the United Kingdom, Ireland, Germany, Italy, Spain, Portugal, Austria, France, Singapore, Japan, Australia, the United States, Brazil, and Mexico. Presenters included artists, communicators, educators, teachers, and researchers. While the primary focus was planetary sustainability, other geoscience themes were also addressed. Some presentations originated in additional scientific disciplines, including space and astrophysics. Nearly 100 contributions have elucidated techniques, methodologies, experiences, and case studies. The majority of presentations involved geosciences coupled with digital and visual art, music and acoustics, and theatre and performance [Lanza, 2020]. Two of our sessions were hosted by the American Geophysical Union (AGU) fall meeting in 2019. In the same year, following a trial period, EGU implemented an artist residency program during its General Assembly in Vienna (Austria).

The sessions at the EGU General Assembly consistently featured annual contributions from INGV. A total of 18 studies were presented, indicating significant interest in the subject matter. Several of these contributions have been published in conjunction with submissions from other institutions in a dedicated special volume [Lanza et al., 2021]. INGV contributions include D'Addezio [2020], Locritani et al. [2020], Menghini et al. [2020], Riposati et al. [2020], and Lanza [2021]. This volume was edited in collaboration with scientists from the European Union's Joint Research Center (JRC) in Ispra, Italy. Since 2015, the JRC has organised a biennial festival dedicated to SciArt. Many INGV contributions have focused on gamification as an effective educational tool. A more sophisticated contribution was presented by my colleague, Graziano Ferrari: "seismic symphonies," a project initiated in 2008. In this project, an artist (Elisa Strinna), a barrel organ builder, and a seismologist collaborated to translate the graphic tracks of seismograms recorded during global earthquakes into a unique soundtrack [Strinna and Ferrari, 2015].

In the EMusic Project, in which I am personally involved as a science communicator, geophysical data - specifically the voltage response collected by the TEM transient electromagnetic method–a well-established geophysical tool for subsurface exploration - are transformed into musical pitches. The resultant music reflects the geological setting and provides a soundscape (an audio component of a landscape). This soundscape serves as the foundation from which a dedicated band improvises jazz music [Menghini et al., 2020]. Figure 3 shows the stage for data acquisition at the Sound from Vesuvius event in 2019. Soundscapes can also be derived from polluted or endangered areas, offering the potential to raise the awareness of planetary sustainability.

The integration of art into scientific communities has demonstrated its efficacy not only as a valuable tool for disseminating scientific knowledge to the public, but also

as a means for scientists and artists to critically examine issues pertinent to their respective fields of expertise. A notable example is the scientific theatre project conducted by Maciel et al. [2021] addressing gender inequalities in STEM careers.

Figure 3. *Preparing for data acquisition. An excerption from the Jamming session with Vesuvius concert can be seen at: https://av.tib.eu/media/49134 (accessed 28 January 2025).*

In some instances, the interaction between scientists and artists has served as a genuine test, prompting those with a more receptive mindset to reflect on the methodological approaches. As noted during the development of the video game *Earth Girl Volcano*: "exchanging points of view was an important part of the interdisciplinary collaboration, and we believe this broadened the horizons of most participating scientists and artists" [Kerlow et al., 2020]. Lancaster and Waldron [2020] conclude that the creation of the visual installation *Boundary|Time|Surface* has enhanced the respective understanding of each other's disciplines, enabling them to collaboratively produce a work that surpasses their individual capacities

in contributing to the dissemination of knowledge about the Earth, time, and humanity's relationship with the planet.

Unfortunately, the EGU sessions on science and art were suspended due to the COVID-19 emergency. However, in 2024, the session organization resumed in collaboration with newly interested geoscientists. Currently, a project is underway with the University of São Paulo (Brazil) focused on scientific clowning [Sand Franca et al., 2024].

Participation in the session, which has grown in significance each year, provides valuable impetus for continued engagement in this endeavor. However, challenges persist due to limited financial resources, which hinder the participation of artists. In general, scientists more frequently attend to present work developed in collaboration with artists. Through the EMusic project, musicians' attendance at the EGU was successfully facilitated, but this remains an isolated occurrence. Some participants have requested permission to display artistic installations at the conference. However, this requires the organisers' willingness to repurpose spaces typically reserved for scientific projects. This highlights the need for cultural evolution to bridge the divide between scientific and humanistic disciplines. Such evolution could be fostered through dedicated interdisciplinary sessions or workshops at scientific conferences, promoting meaningful dialogue between scientists and artists.

7. Implications for Geoethics

As Peppoloni and Di Capua [2015] asserted in their list of ethical obligations for modern geoscientists, it is the responsibility of geoscientists to raise awareness about citizens' duties toward the Earth system through effective communication and targeted education, particularly aimed at younger audiences. One key objective is to disseminate scientific knowledge to engage the public in recognizing geological heritage as a shared and protected resource. Earth and life, in all their forms, should be preserved. Geoscientists are also tasked with promoting the geo-environmental uniqueness of each region, highlighting the connections of its historical, cultural, and environmental characteristics. This involves respecting the bio- and geo-diversity of each environment and employing cross-disciplinary approaches, including collaboration with experts from related fields.

While the introduction of geoethics within the international geoscientific community represents a significant and essential achievement, it is necessary to contextualise this development within a broader cultural framework. The consideration of humanity's trajectory cannot disregard the relationship that society as a whole

maintains with our planet [Peppoloni and Di Capua, 2022]. Furthermore, it is crucial to recognise that the dehumanisation of our society and disregard for our identity can only exert a negative impact on the planet we inhabit. Consequently, geoscientists cannot be solely responsible for identifying and implementing behaviours that promote the values necessary to preserve the planet. This has already been accomplished in geoscientists' reflection on the path and the future of geoethics [Bohle, 2019; Di Capua et al., 2021; Peppoloni and Di Capua, 2022, 2024; Di Capua and Oosterbeek 2023].

Building upon this understanding of geoethics, it is evident that a pluridisciplinary approach is essential to address the complex challenges facing our planet and society. The integration of artistic expression with scientific data enables researchers and artists to effectively communicate the urgency of environmental issues to diverse audiences, thereby transcending conventional communication barriers. This interdisciplinary approach not only enhances public engagement, but also promotes a critical analysis of our relationship with the planet, fostering a more comprehensive understanding of the interconnectedness between human activities and natural systems.

Geoethics functions as a crucial intermediary between these disciplines, providing an ethical framework for decision-making in environmental contexts. The synthesis of art and science within a geoethical framework can facilitate the innovative visualisation of complex data, rendering abstract concepts more accessible to non-specialists. For instance, climate change data can be transformed into immersive installations or interactive digital experiences, enabling viewers to engage with scientific information at a more profound and experiential level [Tosca, 2024]. Such artistic interpretations have the potential to elicit emotional responses, potentially catalysing behavioural changes and policy support for environmental protection. Furthermore, this interdisciplinary collaboration could inspire innovative solutions to ecological problems. Artists may propose unconventional perspectives that challenge scientists to consider alternatives beyond traditional methodologies, and scientists can provide artists with accurate data and insights to inform their creative processes. This cross-pollination of ideas can lead to novel approaches in fields, such as sustainable design, urban planning, and conservation strategies.

The integration of geoethics into this art-science nexus introduces a critical dimension of moral consideration. This necessitates an examination of the long-term implications of human actions on the Earth and future generations. Geoethical principles can inform the development of responsible research practices, sustainable resource management and equitable environmental policies. Moreover, this tripartite approach fosters a more comprehensive and responsible approach to environmental stewardship. It acknowledges that

addressing global challenges, such as climate change, biodiversity loss, and resource depletion, requires not only scientific knowledge, but also innovative problem-solving and ethical decision-making.

Through the integration of empirical evidence, artistic conceptualisation, and ethical considerations, it is possible to develop more comprehensive and efficacious strategies for environmental conservation and sustainable development, which not only produces innovative research and compelling artwork but also educates a new generation of professionals equipped to address complex environmental issues from multiple perspectives.

The intersection of art, science, and geoethics represents a potent paradigm for addressing environmental challenges. This approach has the potential to transform public comprehension of scientific issues, inspire innovative solutions to ecological problems, and promote ethical considerations in our interactions with Earth. As we confront increasingly complex and urgent environmental crises, embracing this interdisciplinary model may be instrumental in fostering a more sustainable and harmonious relationship with our planet.

8. Conclusion

Collaboration between geoscientists and artists presents innovative approaches to address planetary sustainability challenges. This interdisciplinary methodology enhances public awareness, mitigates the human-nature disconnect, promotes comprehensive environmental education, encourages critical analysis, and facilitates innovative problem solving. Experiences at the INGV and EGU conferences demonstrate the efficacy of these collaborations, ranging from geo-mythology projects to artistic interpretations of seismic data. However, challenges persist in the development of appropriate evaluation methods. Future priorities include the following:

1. Developing robust assessment frameworks.
2. Integrating art-science collaborations into educational curricula and outreach programs.
3. Encouraging institutional support for artist-scientist partnerships.
4. Exploring applications to address environmental issues and promoting geoethical principles.

This approach has the potential to engage collaborations in educational curricula and public outreach programs, and foster a more responsible and sustainable relationship with our planet.

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