Chemistry, urban environments and ecopedagogy: A possible dialog.
Soil as a case-study example for an integrated vision

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Abstract

Ecopedagogy can be viewed as a new kind of science education for a more sustainable civilisation; it is often defined as a participatory education centred on life and on love for the natural environment, matching some concepts clearly deriving from an enactivist matrix. However, the noble intentions of ecopedagogy fail to dispel the doubt about the existence of discriminatory aspects towards the anthropic element, mostly seen as invasive and a source of disharmony. Emblematic examples are urbanisation and synthetic chemistry, both involved in the consumption and progressive degradation of soil. This work aims to demonstrate how some interdisciplinary educational activities about soil, carried out mainly *in situ* with an experimental approach, can debunk certain prejudices, focusing either on the improvement of green spaces or on the scientific-technological tools allowing for their protection; these include geo-localisation and the conscious use of chemistry. Anyway, scientific progress alone cannot resolve environmental problems: a change of consciousness, to which school communities are called, is required.

L'ecopedagogia rappresenta un modello pedagogico innovativo per una nuova civiltà sostenibile; essa è spesso definita in riferimento alla dimensione partecipativa centrata sulla vita e sull'amore per l'ambiente naturale, fattore di chiara matrice enattivista. Nonostante i suoi nobili intenti, talvolta l'ecopedagogia non riesce a dissipare alcuni dubbi circa l'esistenza di aspetti discriminatori nei confronti dell'elemento antropico, spesso considerato invasivo e fonte di disarmonia. Esempi emblematici sono costituiti dall'urbanizzazione e dalla chimica di sintesi, fattori particolarmente coinvolti nel progressivo consumo e degrado del suolo. Questo lavoro vuole dimostrare

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come alcune attività di taglio interdisciplinare sul suolo, svolte prevalentemente *in situ* con approccio sperimentale, possono sfatare questi pregiudizi, focalizzandosi sia sul miglioramento degli spazi verdi sia sugli strumenti scientifico-tecnologici che ne permettono la protezione; tra questi, la geo-localizzazione e l'uso consapevole della chimica. Ad ogni modo, il solo progresso scientifico non può risolvere i problemi ambientali: è necessaria una presa di coscienza che parta anche dalla scuola.

Keywords: ecopedagogy; soil; chemistry; urbanisation; environmental education

Parole chiave: ecopedagogia; suolo; chimica; urbanizzazione; educazione ambientale

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1. Ecopedagogy: A short outline

The worldwide debate on climate change, energy problems and pollution testifies how environmental education and sustainable development today represent a challenge that cannot be postponed anymore to empower all citizens, called to adopt behaviours and lifestyles in sign of respect for the environment. The 2030 Agenda for Sustainable Development also draws attention to the importance of an appropriate educational action, to achieve which teachers play a key role (Capobianco & Cerrato, 2022). Paulo Freire (1921-1997) is among the most committed pedagogists in order to conceive an ecopedagogy that is not mere scholastic ecologism, taking into account environmental and social justice in a broad sense (Tona, 2018). The change of perspective that has been affecting teaching in recent decades is leading to a progressive shift of focus from the only achievement of disciplinary objectives to a greater attention towards the implementation of real problem solutions (Bonaiuti et al., 2016). It is therefore important that the school agency becomes an all-round promoter of a new ecological culture to shape a real environmental awareness, beware of the interdependence between the local and global dimensions. In this context, the institution of World Soil Day, celebrated on 5 December every year from 2014, is particularly important; it draws attention to the importance of sustainable soil management. On the occasion of World Soil Day, Italian schools, as part of their organisational and educational autonomy, are also called upon to define educational training courses and propose in-depth information on the topic. The goal of these paths is the development of an "ecological intelligence" allowing humans to interact respectfully and effectively with the environment (Goleman, 2009). According to Daniel Goleman (1946-), the concept of ecological intelligence starts from the "naturalistic intelligence" proposed by Howard Gardner (1943-), defined as the ability to be deeply connected with other living beings, appreciating the effect that this relationship has on us and on the external environment (Gardner, 1999). The conception and definition of this type of intelligence are affected by the enactivism, according to which the cognitive structures of the mind emerge from the sensory-motor dynamics between an acting organism and its environment (Varela et al., 1991); according to some philosophical-ethical enactivist concepts, such dynamics would favour a "type of «enactive listening» at the core of a situated account of love of nature" (Candiotto, 2022). In this framework, the concept of "affective ecology" takes shape, understood as the study of the emotional and cognitive relationships that human beings establish with the living and non-living world (Barbiero, 2017). All life on Earth is part of a large interdependent system that influences and depends on the non-living components of the planet: rocks, soil, water and air. Acting on a part of the biosphere affects the whole. Managing development in such a way that it does not threaten the survival of other species or destroy their habitats is a matter of ethics as well as of practical considerations (Bardulla, 1998). Affective ecology can support a profound understanding of these dynamics, also due to its positive effects on the development of attentional skills (Barbiero, 2011). The soil, from a pedagogical point of view, represents an excellent interdisciplinary and eco-didactic laboratory that provides various ideas for teaching the basic principles of ecology starting from the first school grades. For a better understanding and systemic interpretation of natural environments, an interdisciplinary vision and a systemic-relational approach are required, connecting hard sciences such as chemistry not only with other natural sciences, but also with humanities (Celestino & Marchetti, 2020). In the Italian education system, very split into their disciplines, Italian students obtain low scores in international assessment of scientific knowledge (OECD, 2018). Interdisciplinary approach could be a valid remedy, considering that Italian teachers are well disposed towards system thinking despite their differences in background (Celestino & Marchetti 2020). Soil study is particularly suitable for this interdisciplinary and systemic approach. Moreover, it offers opportunities for participatory sense-making (De Jaegher & Di Paolo, 2007), specifically:

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- perceptual and motor experiences involving biological, affective and cultural components;
- teamwork, taking care of the relational dimension;
- emotions enhancement as a starting point for the construction of knowledge;
- awareness raising about the soil system living world;
- encounter with a part of "reality" characterised by original elements (Guerrini, 2019).

In order to configure educational settings fostering a real ecological sensitivity, it is essential to use proper spaces: with appropriate planning, these can become learning environments in a constructivist - or even enactivist - key. Obviously, it is not enough to simply move beyond the classroom boundaries (Tomarchio et al., 2019; Strongoli, 2019): adequate mediation by teachers as reliable leaders is required (Higgins, 2002). Furthermore, cooperative learning is crucial for civic education challenging beliefs and prejudices: moral decision-making presents differences when taken individually or in groups, in relation to the processes of cognitive dissonance and participatory sense-making (Espinosa-Corrales, 2021).

2. Soil degradation and urbanisation

Soil represents the interface between land, air and water and hosts a large part of the biosphere (Di Fabbio & Fumanti, 2008); it can be defined as a complex, constantly evolving "living system" that provides mankind with the elements necessary for its sustenance. In addition, the soil is a non-renewable and extremely fragile resource that performs many fundamental functions for the maintenance of life on Earth: it is important not only for food production and human activities, but also as a reservoir of biodiversity and an invaluable source of goods and non-replaceable services, essential in particular for agricultural activity (European Commission, 2018). Soil could be perceived by students as a static and lifeless entity, whose loss or degradation would not be excessively problematic for the balance of the ecosystem; on the contrary, it is a dynamic system in equilibrium with the other elements of the surrounding environment that can be seriously compromised by anthropic action. The urban development of cities, the construction of roads, bridges, greenhouses etc., have changed the soil use over time, determining in many cases its degradation through phenomena such as desertification, erosion of the surface layer, waterproofing, salinisation, acidification and pollution (Eni Scuola, 2022). Soil knowledge helps to train citizens aware and willing to work for their own development and for the good of society as a whole (Montanari, 2014).

All the recent programmatic documents developed at European level, from the *Biodiversity Strategy* to the 2030 Agenda objectives (European Commission, 2020a), passing through the *European Green Deal* (European Commission, 2019) and the *Farm to Fork* strategy, (European Commission, 2020b) call for a more efficient and sustainable use of resources, developing solutions for restore the integrity of degraded soils through: fertility protection, erosion reduction, the use of biopolymers for soil stabilisation, waterproofing adjustment, decontamination, etc.

One of the most relevant outcomes of these documents is given by the European project *Soil4Life*, involving Italian, French and Croatian partners, aimed at improving the governance of decision-making processes regarding soil at national, regional and local levels. In Italy, at national level, a *White Paper for Sustainable Soil Management* was produced (ISPRA, 2021). At the local level, the observatories on soil consumption monitoring and on the Regions and Autonomous Provinces territory sustainable planning have been set up.

It is now evident the need to overcome the anthropocentric model in which man claims the right to use the Earth's resources in an unrestrained way; it is necessary leaving aside the dichotomy putting Nature and Culture

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on two opposite sides, in favour of an ecological thought globally understood. Pope Francis too is reiterating on several occasions that a real ecological conversion is necessary to respond to the impending ecological catastrophe (Balzani, 2022).

The state of health of a soil has repercussions on water resources, air quality, plant and animal biomass, with obvious consequences on the entire food chain. Therefore, soil deterioration can affect our health and endanger the safety of products for human and animal nutrition (European Commission, 2006). The soil resource must therefore be protected and used in the appropriate way, in relation to its intrinsic properties, so that it can continue to perform its irreplaceable and efficient function on the planet (ISPRA, 2014). Studying paedology is therefore important to approach complex systems knowledge and to understand the veritable meaning of "resource" (D'Alessio, 2021). As John Dewey (1859-1952) stated, school is a miniature society that offers the possibility of correcting inappropriate behaviour, establishing relationships of cooperation and mutual respect. In the school environment, the relationships are two-way: the pupils' positive response to the educator's proposals derives from his ability to inspire trust; he must be credible, authentic and consistent (Pileri, 2015). In proposing a pedagogy of the soil enabling students to become aware of a renewed idea of citizenship (Rollini et al., 2022), the importance of green areas and waterways in their own territory emerges in a clear way. In Milan, for example, large city parks or green buildings such as the *Vertical Forest* have lower temperatures than the more cemented areas.

For the study of the influence of urbanisation, the topic can be dealt with by reading natural indicators (herbaceous, tree and shrub cover, ratio between natural surfaces and artificial and waterproofed surfaces, wetlands, etc.). It is therefore necessary to analyse the damages due to the urban environment directly by the reduction of the presence of natural indicators and the increase in waterproof surfaces, with the inevitable consequence of the rise in urban temperatures and phenomena of instability because of the lack of rainwater regimentation.

The presentation of some good practices about new theories on sustainable urban growth, can provide students with an overview of the possible forms of mitigation of damages related to the aforementioned phenomena. It is possible to build while always keeping under control the balance between green and urbanised areas (where, moreover, today it is also possible to intervene with materials with a high level of permeability). Current guidelines aimed at the redevelopment of degraded areas and regeneration of cities portions are exemplary: they stem consumption of new soils for the benefit of the reuse of already built-up areas.

3. Pollution and soil: A historical digression

Certainly, in the study of soil chemical aspects cannot be confined to simple measurement of parameters; just think of synthetic fertilisers to get an idea of the central role of chemistry in soil use. Unfortunately, there are still many misconceptions about the role of synthetic substances leading to a veritable *chemophobia*, according to which everything "chemical" is a source of danger, while everything "biological" is good and positive (Rollini et al., 2022). Let us trace back some of the reasons for this hostile attitude toward chemistry.

Damages due to the intensive production of chemicals highlighted from the 1960s, caused a progressive loss of faith in science in the society. It is possible to establish a precise year as a reference point for this phenomenon: Rachel Carson (1907-1964), a marine biologist, published "Silent Spring" (Carson, 1962), which brought the environmental impact of synthetic pesticides to the attention of the American public. Most chemical companies rejected Carson's reports, but her message nonetheless spurred action initially at national, then at international level: a general renewed environmental awareness led to the formation of the U.S. Environmental Protection

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Agency (EPA). Many pesticides were banned or their usage was restricted, in particular DDT (that gained popularity after its use during World War II to prevent the spread of diseases such as typhoid and malaria).
Carson explained how insecticides can kill birds that feed on insects harmful to plantations, moving through the food chain and the natural environment, causing immediate and long-term consequences. She carried out very extensive research, studying dozens of reports and interviewing experts, demonstrating that chemical-based agriculture can result in extreme soil desertification and erosion. Her purpose was not to ban all the chemicals used in agriculture, but to understand the risks to human health and environment and to evaluate other products' usage or biological alternatives (Bishop, 2012).
As Carson poetically described, soil is a very crowded and organised realm, full of industrious microbes producing chemicals that are a basic condition for healthy plant growth. Moreover, soil plays a fundamental role in carbon sequestration, as healthy soil can store excess carbon dioxide from the atmosphere. Industrial farming techniques (e.g. tillage and continuous monoculture), can damage the topsoil extensively, so that an increased amount of fertilisers are required. Unfortunately, an exaggerated use of fertilisers leads to soil biodiversity further decreased. The consequent degraded soil is less resilient to extreme weather events, leading to air and water pollutants as pesticides. Such a situation becomes more severe over time, to the point that the eroded and degraded soil is abandoned.
Conventional agricultural practices are used to meet the food demands of a growing global population, but in this way we will inevitably despoil the earth for future generations, accelerating global warming and creating unstable climate. Production, transportation, and application of both pesticides and fertilisers release greenhouse gases related to rising global temperature levels. Eroding soil by intensive farming and urbanisation can also cause the releasing of sequestered carbon dioxide back into the atmosphere.
After the publication of the book, a virtuous process began among professional chemists as well, focusing on more sustainable practices. Even now “Silent Spring” is universally considered a text that changed the world: it suggested a needed change in how democracies operated, in order to allow individuals and groups to question governments’ environmental choices. It is no coincidence that a monographic issue on ecopedagogy was dedicated to Rachel Carson (Bianchi, 2020a).
Carson's report became known worldwide, therefore chemists’ awareness about the impact of chemical products slowly increased towards the development of new areas of research dedicated to the study of the environmental equilibria (environmental chemistry) and of their maintenance in coexistence with the production and usage of chemicals (green chemistry). The first important environmental chemistry publications about natural waters (Stumm & Morgan, 1970) and atmosphere (Molina & Rowland, 1974) appeared in the 1970s, whereas green chemistry was founded in the early 1990s.

4. The rise of Green Chemistry

Through environmental chemistry, the natural processes of Earth as well as the impact of human activities are studied; in the last few years the number of publications of this sector, also intended for the general public, has been growing to raise awareness about pollution’s consequences (Sizmur, 2016). This kind of study contributes to solving challenges related to food, energy, and natural resources (Zalasiewicz et al., 2010). Environmental chemists promote conservation and protection of the natural environment by monitoring sources of pollution and extent of contamination; they examine how chemicals interact with the environment, trying to forecast short-term and long-term consequences of such interaction.

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The environmental chemistry role has been increasing worldwide because of the growing pressures to protect human health from exposure to hazardous chemicals (IEA, 2016). Therefore, they provide regulatory support dealing with very complex problems. Nowadays many chemical companies employ environmental chemists to be in compliance with government regulations. Environmental chemistry focuses on the effects of polluting chemicals on nature, whereas green chemistry (also called "sustainable chemistry") focuses on technological approaches to prevent pollution and to reduce the consumption of non-renewable resources (Jeon, 2018). According to a more accurate definition, "Sustainable Chemistry is the design, manufacture, and use of environmentally harmless chemical products and processes to prevent pollution, produce less hazardous waste, and reduce environmental and human health risks" (Carra, 1999). Paul Anastas (1962-) coined and defined the term "green chemistry", launched the first research program in the field and co-authored a ground-breaking book in which the "12 Principles of Green Chemistry" were outlined (Anastas & Warner, 1998); thirteen years later he wrote:

> "Rather than continue deferring to litigators, legislators, and regulators to reactively handle these critical problems, members of the chemistry community unified around a common goal: to design chemical products and processes that reduce or eliminate the use and generation of hazardous substances" (Anastas, 2011).

The rise of green and sustainable chemistry has been described as some sort of revolution, like the agricultural and industrial revolutions that characterised other periods in previous centuries.

5. Students' perception of chemistry and environmental science

However, the green chemistry revolution has not succeeded in eradicating chemophobia in industrialised countries: this is evidenced by an alarming disaffection for science and chemistry in particular, as revealed by the ROSE project, *The Relevance of Science Education* (Sjøberg & Schreiner, 2010). The purpose of ROSE was to gather and analyse information on 15 years old learners' attitudes towards science and technology and their motivation to learn scientific subjects. Examples are: interests in specific science topics, views on science in school, attitudes toward science and scientists, aspirations, feelings with regards to environmental challenges, etc. The report showed clearly: an overall pattern in which pupils from the less developed countries express the highest interest in science (gap between northern and southern countries is particularly accentuated for chemistry); a certain mistrust - either in students from developing areas or in students from industrialised countries - in their ability to have a direct impact on the resolution of environmental problems (they think that is opportune to delegate this task to the "experts").
Therefore, the results of the report paint a worrying picture. The survey was conducted before the fame of the activist Greta Thunberg (2003 -); it would be interesting to conduct it again. Anyway, it must be taken into account that even youth movements sometimes turn towards an extreme ecologism that is not only naive, but also unproductive (if not counter-productive). A mature ecological vision, far from easy simplifications, is represented by an ethical anthropocentrism, truly interdisciplinary, considering the human being as an architect within the process of natural and artificial harmonisation (Luzzini, 2022).

6. Ecopedagogy, chemicals and urbanisation

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It is necessary to remedy the lack of scientific vocations by reconciling ecopedagogy with anthropic intervention, in particular with the processes of urbanisation and chemicals production - for example by showing both the decisive contribution of chemists in improving standard of living and their decisive contribution in regulatory activity (Celestino, 2013). These considerations should be accompanied by philosophical considerations highlighting the shortcomings of a certain enactivism variously linked to forms of panpsychism earlier mentioned (Candiotto, 2022); some critical reflections have already been formulated:

> "If we label the creation of urban places as a "story of violence," are we not implying that human intervention is to be conceptualised as violent? Can we then speak of love of cities at all? And are we not falling into discriminatory biocentrism?" (Lopez-Cantero, 2022)

Roald Hoffmann (1937-) has already pointed out how an idyllic view of the past overshadows the cruel aspects of nature (Hoffmann, 1995). These latter reflections make it possible to comparing the invention of chemicals to the process of urbanisation: both are usually labelled as "artificial", with a negative connotation. Hoffmann explains these prejudices with the existence of *biophilia*, the innate human tendency to focus one's attention on life forms and to become emotionally attached to them (Wilson, 1993). Biophilia is closely connected to affective ecopedagogy (Barbiero, 2017) influenced by enactivism**.** The danger that ecopedagogy will result - regardless of the real intentions of scholars in the field - in a new form of rejection for the artificial element, chemical or urban, is very real. One of the remedies proposed by Hoffmann consists in a different approach from chemists, more sympathetic towards the layman, using forms of communication that induce the ordinary citizen to more rational and cautious considerations. Indeed, we must avoid minimising the fears of non-experts without first providing the necessary tools for reflection (Hoffmann, 1995). We are in fact conditioned by a "liquid fear" (Bauman, 2006/2017) that heavily conditions our orientations. It is also important, especially for teenagers, to avoid adults feeling completely resigned to the advent of environmental disasters usually presented as inescapable (Bartolini, 2021). Engaging students in educational projects in which they play an active role, could alleviate the sense of powerlessness among adolescents emerging from the above-mentioned survey (Sjøberg & Schreiner, 2010).

In addition to the communication aspects, a chemistry teaching approach characterised by a historical perspective is very effective in highlighting the flaws of a certain ecopedagogy, lacking in the recognition of the "artificial" element as a positive factor of progress.

The chemical industry, through the production of synthetic fertilisers much more efficient than natural ones, contributed decisively to feeding a world population that was preparing to double between the '50s and '70s of the past century. We owe the mass production of synthetic fertilisers to the emblematic figure of Fritz Haber (1868-1934): on the one hand harshly criticised for his research on chemical weapons on behalf of the Nazi regime (of which he himself was a victim as a Jew); on the other considered a benefactor, the man who "made bread from air" (Essex & Howes, 2014). Because of this historical dualism in the use of chemistry, the role of this science remains unacknowledged in ecopedagogical studies, in the same way as the benefits of urbanisation (an example is the reclamation of the Pontine marshes and the following foundation of cities on the reclaimed land). The bio-anthropological aspects are preferred, but they do not help to unmask prejudices and fake news such as those frequent in chemistry (Domenici, 2022). Intensive agriculture and unbridled urbanisation are causing alarming soil erosion, but the factors at play need to be critically evaluated. Education plays a key role, stimulating the development of critical thinking, especially through direct experimentation in a real context. It is possible to report countless cases of everyday life representative of distorted interpretations relating to the

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world of "sustainable" products: for example, synthetic silica gel cat litter is harmless compared to clay litter, wrongly considered "ecological"; actually, clay litter is commonly produced in an environmentally degrading process using strip mining, that removes the surface layer of the soil undermining its fertility almost irreversibly (Celestino & Marchetti, 2015). Unfortunately, the adjectives "ecological", "biological" and "sustainable" are frequently misused, to the detriment of synthetic products often more sustainable than those naturally sourced.

7. Ecopedagogy: Didactic, political, epistemic issues

The previous reference to Bauman (2006/2017) is significant in the light of the repercussions in the intimate sphere: Figure 1 shows the social and environmental spheres as progressive expansion of the personal sphere (Sauvé & Godmaire, 2004), in line with the concepts of mental-subjective ecology, social ecology and environmental ecology (Dozza, 2022).

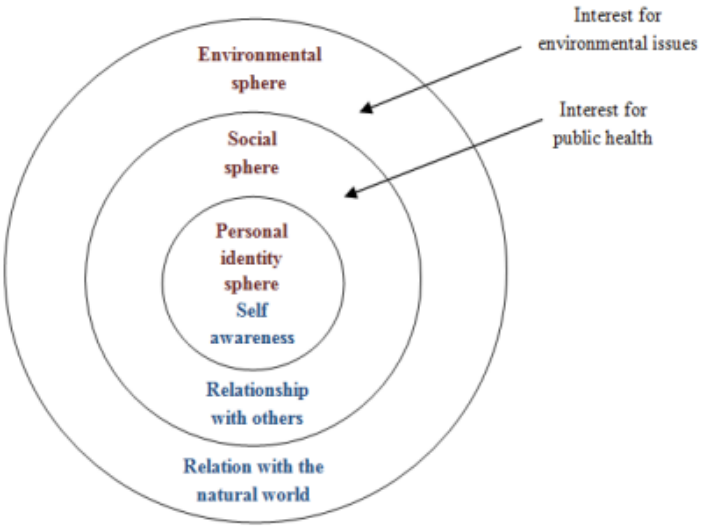

Figure 1. Personal, social and environmental spheres

The consideration of an intimate individual sphere - which feels threatened by ecological imbalance - makes the systemic approach necessary but not sufficient in dealing with complexity at an educational level: focusing on measurable cause-effect-remediation relationships, it is of little use in piloting feelings such as fear and disillusionment. Instead, a holistic approach is needed, as opposed to the reductionist one - thinking in systems tries to achieve a sort of reconciliation between these two antithetical visions, between which systemic thinking acts as a bridge (Cabrera & Cabrera, 2015). Systemic and interdisciplinary thinking is undoubtedly to be encouraged to tackle complex problems, as long as it does not in turn lead to a technicist and paradoxically simplifying vision, a frequent trend when ecology is limited to the sole field of STEM disciplines: flow charts will never be able to fully express the fundamental role of humanities in the global understanding of environmental phenomena. It is necessary to acknowledge the existence of a discontinuities along the various fields of knowledge, that only a qualitative gaze is capable of grasping (Hoffmann, 1995); that requires not improvised theoretical constructs but highly educated teachers, interested in cultural areas other than the one in which they are specialised (Toadvine, 2011).

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On the basis of these considerations, as already highlighted in the scientific literature, the ecopedagogy movement moves towards complex thinking and holism (Norat et al., 2016).

In particular, the subjective and affective dimension requires a holistic point of view characterised by other ways of approaching reality, giving place to other - creative, intuitive and experiential - ways of understanding the world. The students perceive that we are part of selfish societies crushed on the present and without trust for institutions, especially in taking care of the younger generations in the name of a truly sustainable development. We are in the age of "sad passions" (Benasayag & Schmit, 2003), characterised by facade changes that do not undermine the inexorably neoliberal tendency in socio-economic competition and in natural resources predatory hoarding. In a difficult context like this, the school should encourage participatory approach and critical thinking. Participation elicits reflection about the relevance, the usefulness and the purpose of the produced knowledge, encouraging the students to assume collective responsibility for the shared environment, which includes making political claims and political action. The participatory approach stimulates collective investigation and discussion, providing a framework for clarifying ethical standpoints of each participant. Furthermore, participation fosters the sense of "ownership" of the project, enhancing the school community solidarity and developing some competencies at the same time (Robottom & Sauvé, 2003).

Participatory action, critical thinking and ethical standpoints are extremely important in order to define an "ecosystem approach" in education (Sauvé & Godmaire, 2004), avoiding degenerations as described in relation to some Italian "schools in the woods" for children: not infrequently they practice "environmental miseducation" and support neoliberal logics that undermine social cohesion, especially in combination with some forms of libertarian education. According to Pavesi and Dal Lago (2021) that happens in the following ways:

- These schools promote a non-scientific relationship with nature, uniquely ecstatic and romantic, hindering the maturation of a true ecological awareness. More than "nature" they seem to speak about "countryside", understood as a harmonious, balanced and substantially static environment, where man can live happily if he learns to know, love and respect it, without pretensions of intervention. This vision is connected to an autarkic and unsustainable model of society (whose fragmentation would increase the circulation of goods and related services).
- The educational proposals recall the nineteenth-century contempt of the aristocracy towards proletarian cities and the fascination for the uncontaminated, non-anthropised world. These perceptions foment class hatred, also in light of the fact that these schools are attended by upper-middle class families.
- School "forests" are anthropic environments, built and managed through human intervention, therefore in a way artificial. Outdoor education projects offering guided and structured tours could be preferable, allowing a mediated - not spontaneous and casual - child's relationship with the environment.
- Some schools in the woods practice forms of participatory democracy in which children have a say in firing school staff (!). Beyond the pedagogical absurdity of loading a child with such a great responsibility, it is clear that these organisations are converging in the economic neoliberal front, which intends to extend the action of the market as a regulating principle to the entire education system.

It is clear that we are not dealing with a form of "education as a practice of freedom" (Freire, 1973), since in this case the concept of freedom is not defined in relation to responsibility towards others and the environment; nor it takes into account the complexity of situations, promoting a simplistic vision of the relationship between nature and culture. On the contrary, ecology is a complex knowledge, whose theoretical bases are set on principles of sustainability, ethics of care and global citizenship, offering an alternative project to economic liberalism (Norat et al., 2016); it is therefore defined by a plural paradigm, giving rise to an extremely varied field of research and intervention, with different investigation methodologies, taking into account the connections among

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heterogeneous elements in multiple contexts, natural and non-natural. As a consequence of this plurality, the ecological paradigm renounces its theoretical-methodological compactness, but broadens its productivity and encourages divergent thinking (Dozza, 2022). Even pedagogical knowledge, despite its autonomy, is a plural knowledge, therefore it will inevitably tend to establish relationships of "fertile hybridisation" with other knowledge networks, generating educational issues fitting individual training needs (Spadafora, 2017). Therefore, ecopedagogy derives from the fruitful hybridisation between ecology and pedagogy; the latter as a bearer of meaning of the various scientific and practical dimensions of reality due to its critical, rationalist, committed character (Baldacci, 2004), aimed at promoting an idea of society based on justice, solidarity and awareness. Especially after the welfare crisis, pedagogy must ensure that knowledge is rooted in reality as an embodied simulation that feeds on itself, expands, regenerates itself as embodied cognition (Margiotta, 2012), trying to interpret complex issues without prejudicial positions. In support of this approach, Margiotta (2015) defines pedagogy itself as a "discourse on transformations even within complexity" (p. 217, auth. trans.). The understanding of complexity is never complete, but the mere effort to read the dynamics of the present time in depth makes it clear that our societies cannot afford neither technolatry nor technophobia, as Puleo (2019) has highlighted in an ecofeminist key.

8. Ecopedagogy vs. environmental education

Environmental education can find an epistemological legitimation within ecopedagogy, overcoming the prescriptive character that has hindered an effective and widespread educational action, making hard the relationship with other disciplines. In particular, environmental education presented (and presents) some problems related to its harmonisation within science teaching. For more than thirty years, more and more governments introduced environmental education in school syllabuses (often without getting the expected results); this change occurred by introducing some learning objects in different single subjects or across the disciplines. Another way was the implementation of optional environmental projects in schools. For example, in the 1980s, some authors observed that the barely dynamic nature of the relationship between teachers and students doesn't encourage debates during the science classes; it is well documented that the most frequent environmental education process is limited to information about the environment, neglecting critical skills development (Maher, 1986): teachers try to avoid controversial situations in order to maintain discipline, or because they consider environmental issues too complex to be dealt with. Moreover, some studies highlighted a teachers' lack of interest and training about the environmental education (Papadimitriou, 2001). However, difficulties don't lie solely on teachers' attitudes: many students are unable to overcome their dependence to disciplinary knowledge and to discuss topics at very deep levels, being unfamiliar with open-ended tasks. Therefore, a frequent problem is the gap between government requirements and real teaching practices, as demonstrated at primary level in the UK (Littledyke, 1997). These problems are still present in many school contexts, representing a serious obstacle for an authentic environmental education, aimed at critical awareness development. For example, the societal dimension of chemistry as it is taught in the schools needs further significant improvements (Hofstein et al., 2011).

To assure the interdisciplinary approach required by the environmental education, educators have to be flexible, abreast of teaching methods and adequately trained. As mentioned in the first part, the documents drawn up by the European commissions are the sign of an increased sensitivity to environmental issues, resulting in a greater teachers' involvement.

Ecopedagogy is not only education, it is not only science: it is a pedagogical model integrating science and environmental education. Environmental education teaches to respect nature; ecopedagogy teaches us to ultimately

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respect ourselves as part of nature - and at the same time capable of intervening on it through the introduction of artificial elements resulting of our ingenuity. Ecopedagogy promotes an ethical anthropocentrism in which scientific knowledge and participatory feelings are integrated into a vision of nature devoid of naive sentimentality, stimulating the active intervention of the communities involved.
"Help Your Child to Wonder", wrote Rachel Carson (1956/1998) in a text rightly considered important for ecopedagogy (Bianchi, 2020b), testifying how her pedagogical aesthetics did not exclude the sense of astonishment; and yet it must be reconciled with the scientific method, the same one that Rachel Carson has applied in herinvestigations. Moreover, even Maria Montessori (1870-1952), who had attended a technical institute before studying medicine, in one of her works (Montessori, 1947/2007) had insisted on the importance, for the child, "of scientific knowledge as the astronomy, geology, botany, physics and chemistry, in order to arouse his curiosity and, above all, his amazement in front of life and nature"; for Montessori, the concept of life is linked to nature, freedom and humanity, supported by the knowledge of scientific disciplines (Babini, 2020).

9. Educational project

The following example describes a laboratory-based education project on combating soil degradation in the green areas of one's neighbourhood, carried out at the Liceo "L. A. Seneca" of Rome, with two fourth-year classes during the 2021-2022 school year, as part of the SUSA Competition promoted by the National Institute of Nuclear Physics and the University of Rome "Tor Vergata", with the support of the Smart Urban Sustainable Area Project (INFN, 2022). The aim of the competition is to make young people aware of sustainability issues and to make them protagonists of change. Participation in the competition was accompanied by seminar meetings[i].
The students involved, classified at the second place, were awarded during the official ceremony on May 9, 2022, at the Faculty of Economics of "Tor Vergata" University.
The methodological choices were made in a context still marked by the health emergency, which saw a combination of distance learning and field-based geo-localization work. The objectives were: to make the students aware of the protection and enhancement of the environment in which they live and interact, with a particular attention to soil chemistry and to chemistry-based sustainable solutions; to introduce them to the world of geographical information and information systems management (also in view of future study choices) as a means of intervention on the sites concerned.

10. Geographical information systems

Nowadays, everyday life is permeated by mobile devices that use geo-localisation tools; all the devices used have GPS antennas[ii] and access the Internet in a sufficiently high-performance manner: just think about road navigators indicating the quickest routes to the desired destination avoiding traffic and delays, or the applications allowing us to locate services such as pharmacies, restaurants, hotels and more. Every day we are confronted with and use, sometimes almost unconsciously, algorithms capable of identifying a place through a pair of geographical coordinates included in a reference system and using certain parameters, for example: the search for an accommodation facility that welcomes animals, included in a given price range, located within a certain distance from the historical centre of a tourist resort and offering specific services, etc. All these elements make it possible to refine and customise a search that ends with the identification of a point, or a series of points, in a map system. Geographical Information Systems (GIS), have significantly become part of our daily lives, facilitated by the increasing availability and affordable prices of mobile devices (smartphones, tablets, navigators, etc.) and personal computers (and not only)[iii], capable of using the internet to exchange data and information in infinitesimal

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timescales. The Internet has shortened the distances between people and things, allowing incredible spaces to be covered at the click of a mouse and enabling access to knowledge in a more democratic way.

In this technological context, access to large quantities of data, now increasingly available in Open format[iv], makes it possible to approach knowledge in a different way than in the past and, probably, in ways that are easier for young people. It is precisely for this reason that it is important to be able to recognise the quality and reliability of data and their sources, and to promote training courses aimed at providing students with the tools they need to access information on the web and to guide them in its use.

In recent years, geographic data, the so-called "geodata"[v], have made their appearance on a massive scale. They constitute the graphic synthesis of geographic information and can represent a real phenomenon in its spatial, temporal, and thematic components. Their use makes it possible to generate predictive applications and services aimed at analysing environmental, territorial, and economic issues. For this reason, geodata proved invaluable for the experience undertaken with the classes of the Liceo "L.A. Seneca", an activity focused on analysing the importance of mitigating the effects of indiscriminate land consumption, in an urban context known to the students. In this way, the students perceive that they can play a role in urban regeneration strategies, an awareness of great pedagogical value (Lombardi, 2022).

Over the past thirty years, school curricula have undergone a progressive impoverishment of the study of geography, with tangible consequences in the learning of all those phenomena related to it (historical, economic, political, etc.). The repercussions of the lack of appropriate "geographical education" have become evident over time[vi]. Fortunately, today we are also seeing a reversal of this trend at an institutional level: public administrations are making increasing use of these tools. Over time, there has been a progressive evolution of cartography: from the traditional format to digital and geo-topographic databases.

Today, free access to the large geographic databases[vii] offers indescribable advantages if one considers the possibility of using them synergistically, if one gives students the tools to understand the importance of the arising phenomena, and if one provides them with the means to carry out simple environmental, geomorphological, as well as historical and economic analyses. Therefore, it is important to promote the dissemination of geography. The availability of geodata, as outlined above, now makes it possible to review the role of this subject through activities to be carried out directly in the field, with the advantage of involving the student and making him feel that he is the protagonist of his own actions.

11. Educational activities on geographic information systems

The students attended a three-day face-to-face and distance meeting concerning the topic of soil consumption, starting with the definitions that indicate various activities implying land transformation. Through a brief *excursus* into the world of geographic information systems, various types of geographic databases were presented, very useful for analysis, knowledge and study about the effects of human activities involving soil degradation and sealing.

During some laboratory activities, the students browsed open-access web platforms (OpenStreetMaps and Google Maps), experimenting with the use of applications such as Google Earth for visual analysis of the territory.

The area examined was the Pineto Urban Park (Figure 2), specifically the extension between Pineta Sacchetti street and Valle Aurelia, where the village of the "fornaciari" of the ancient San Pietro factory was located[viii].

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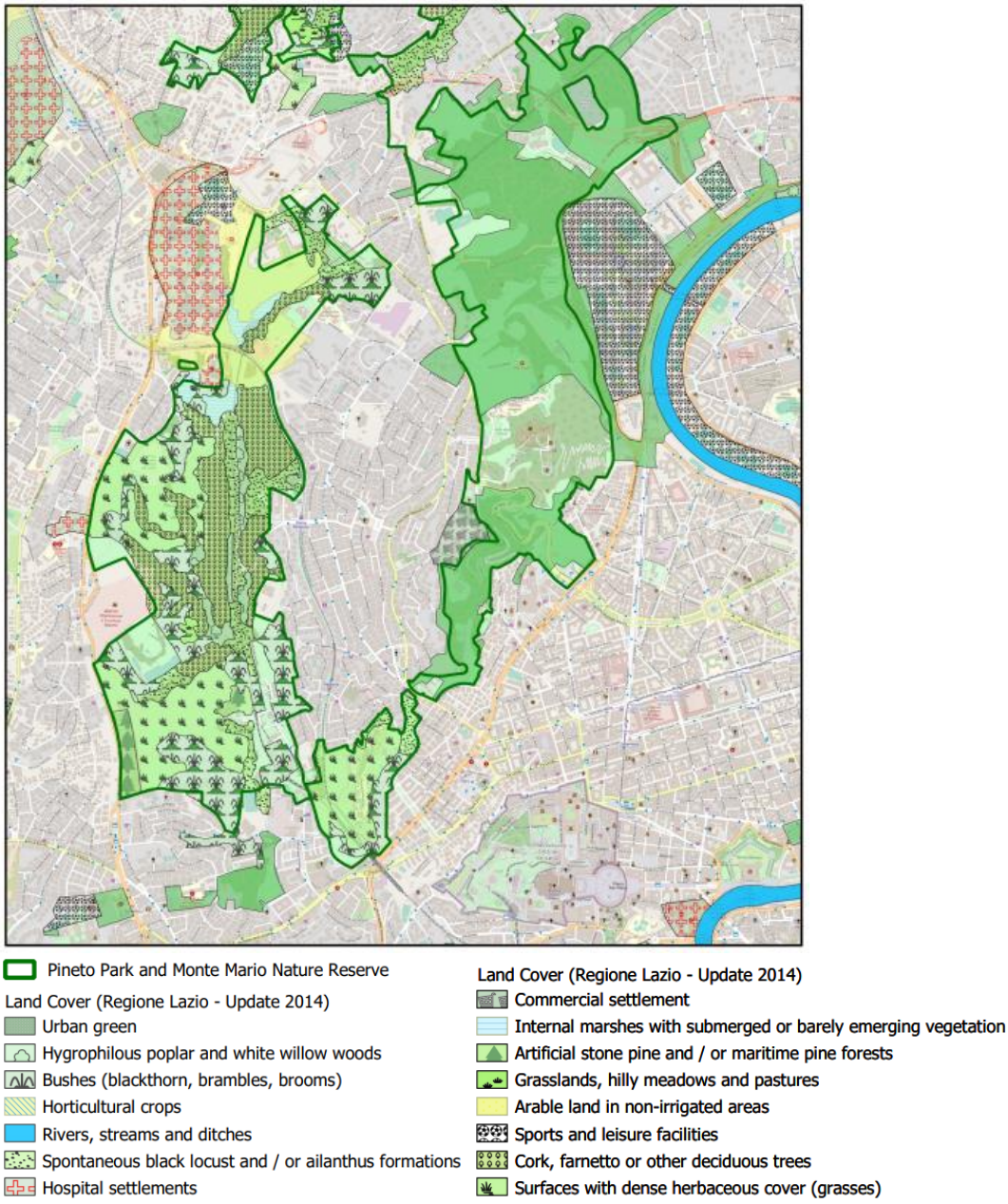

Figure 2. 2D land cover map of Pineto Park. Image from Regione Lazio, CC By 4.0.

The park is close to the school frequented by the students involved; it is also their meeting place, where they usually experience contact with nature.
For the analysis of the natural heritage, the students examined the dataset of the Land Use Map (CUS)[ix]; for the landscape value of the area, the information database of the Regional Territorial Landscape Plan (PTPR)[x] was acquired, a fundamental tool for the protection and enhancement of the territory.
The information was synthesised in some 3D maps and documented through photographs and videos realised by the students directly in the field.

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The indications acquired allowed the students to draw up an abacus of possible interventions aimed at enhancing the area they are familiar with: from the maintenance and protection of the greenery to the enhancement of the park's infrastructure (paths, benches, etc.), from the provision of areas for parking vehicles to the restoration of the Valle Aurelia railway station, etc.

12. Educational activities on soil chemistry

Soil chemistry was examined by specific texts (Radaelli & Calamai, 2005), open learning and activities in order to implement a chemical education beyond the book inspiring passion and curiosity (Tortorella et al., 2019). The students were able to observe different soil types in the Pineto Park, ranging from sandy to loamy (Figure 3), trying to relate the observed soils to those on the geological map provided (Figure 4).

Figure 3. Some soil types in the Pineto Park.

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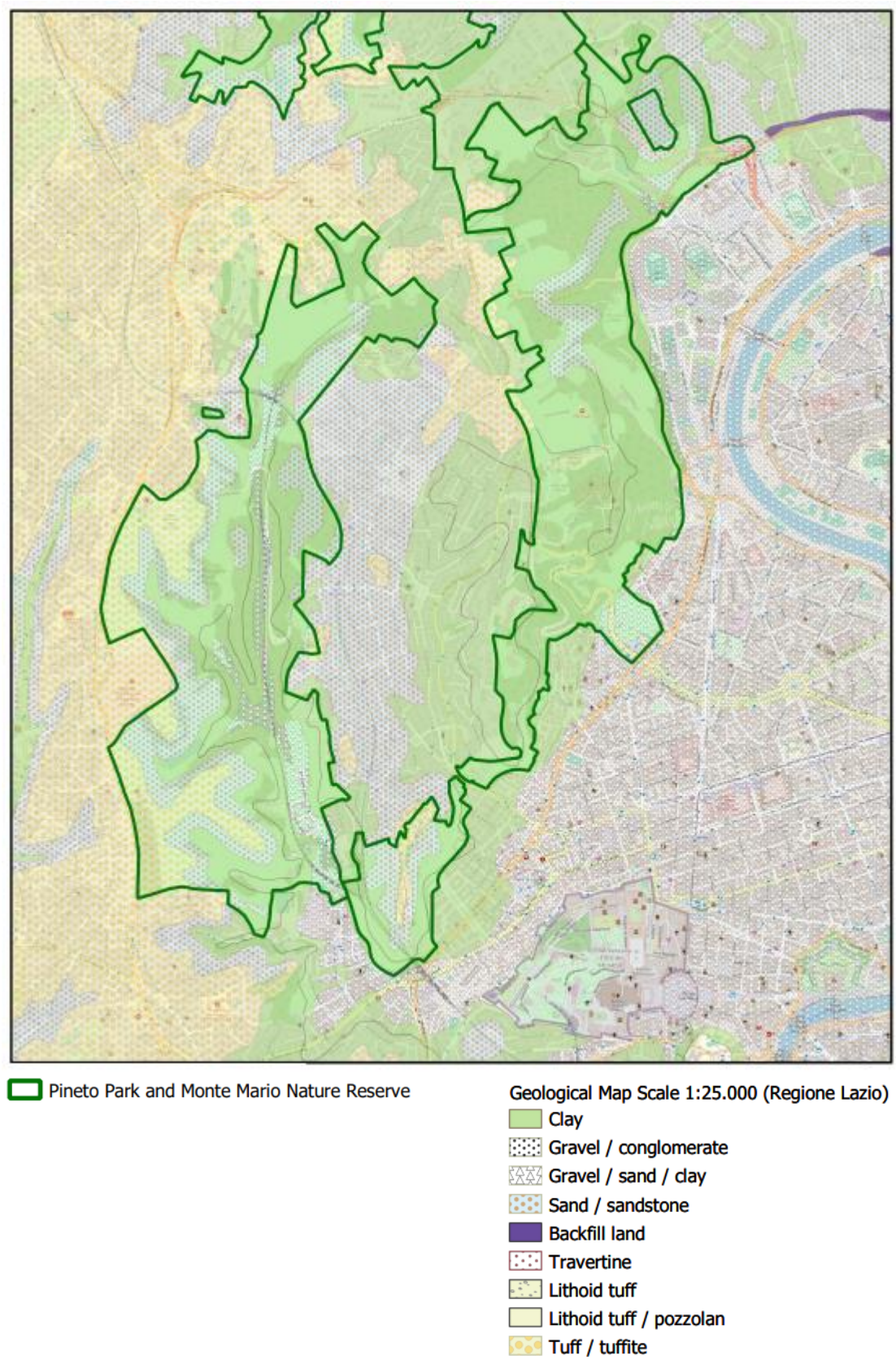

Figure 4. 2D geological map of Pineto Park. Image from Regione Lazio, CC By 4.0.

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Through laboratory activities they measured some chemical-physical parameters of samples from different park locations, observing that the soil is sandy in some sites, clayey in others. Traces of about two million years of geological history can be found in the park, from the derivatives of marine sediments to the eruptions of the Sabatino volcano. A spot of the park called Sabbie Rosse offers a striking spectacle, thanks to the particular red-brown hue of the sandy part before sunset. This effect is due to the chemical composition of the iron-rich sands. Once exposed to rain and wind, this element tends to be oxidised, taking on the characteristic "rust-red" colour. The students also delved into issues related to the presence of pollutants, the alteration of soil composition following fires, etc., examining the fundamental role of chemistry in implementing corrective measures by appropriate fertilisers, soil improvers, soil conditioners, or by the use of properly analysed irrigation water, etc.; the role of chemical sciences in environmental protection was highlighted, with some historical digression on the misuse of chemicals and the green chemistry achievements in proposing sustainable solutions, in particular for the correct soil maintenance (for example, with regard to plastic pollution) (Campanella & Suffritti, 2021).
Simple experiments were carried out, such as the determination of texture, pH, porosity and so on. Moreover, the importance of organic matter for its influence on soil chemical properties (e.g. buffer capacity, redox potential) was understood.
The historical perspective allowed a critical look at the importance of chemistry, in particular environmental and green chemistry.
Chemistry is connected to geology not only by the study of soil: geochemistry is extremely important for the choice of building materials and for their technological optimisation. There is no building activity that does not involve the chemical industry, heavily involved in the research of technological solutions aimed at promoting sustainable development with a triple role: reducing emissions through the continuous improvement of industrial processes and replacing some chemicals with others characterised by a lower environmental impact; allowing the reduction of energy consumption and carbon dioxide emissions during the daily use of buildings, with a decisive contribution to the fight against climate change; offering affordable innovative and sustainable products for industrial transformation activities along the entire construction chain (Federchimica, 2010). For example, within applications of geotechnical engineering works (road construction, erosion control, foundation of buildings) the use of biopolymeric additives such as xanthan gum to stabilise the soil is being tested in order to replace cement, considered not environmentally friendly (Bagheri et al., 2023). Some soil improvers are also polymers: they are used in order to increase soil performance, improve agricultural drainage, reduce water consumption and reflux.

13. Composing with Gaia

During the various phases of the activities, the students were stimulated to develop a scientific vision of ecosystem processes opposed to the spontaneous one. Even the trees in the Pineto Park are the result of human intervention, as is their school building; inside, radioactivity could be detected due to radon, a natural element common in Lazio rocks and therefore present in many buildings. Nature must not be classified as "benign" or "malignant", but according to other interpretative categories. Future adult citizens must know that the survival of the human species will not depend on the consumption choices of the wealthy classes, or on falsely virtuous examples, but on the capacity for rational cooperation and interaction on a planetary level.
Both public investment in scientific research and supranational coordination are of paramount importance, especially at the urban planning and chemical production level, also in direct conflict with market regulation.

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The students became aware about the value of cooperation and dynamic local-global connections, understanding that no effort is useless if well-coordinated.
Some training steps concerned the importance of the technical-scientific aspects in sustainable development, illustrating some examples of smart cities, or showing chemistry's role in solving global issues such as climate change, pollution, energy crisis and food security.
Obviously, the technique alone is not enough: a *change of consciousness* is needed starting from school and university, where the distance between humanistic and scientific culture is still alive despite the numerous interdisciplinary research fields now established (e. g., ecological humanities), as testified in her manifesto for a new idea of science, the "slow science", by Isabelle Stengers (1949-) (2013/2018), an anti-positivist and anti-reductionist scholar who switched to philosophy after studying chemistry.
The slow science requires "slow research" and "slow teaching", whereas the neoliberal discourse conceptualise education in terms of learning outcomes, as a product or process leading to behavioural changes or accumulation of human capital (Biesta, 2005):

> "There is always plenty of time for long reflective walks and enjoyment of the fragrance of roses. Substantial and sustainable research findings might be a combination of fumbling, making serious mistakes, in-depth reflection, collegial dialogue and recurrent interpretations and analysis. [...] Slow researchers relate to teaching—that is, the reciprocal and collaborative construction of research-like learning environments based on enthusiasm, inspiration, pleasure, playfulness, authenticity and a sense of belonging—as a site for testing ideas and plans for research and/or contemplating existing bodies of knowledge in intellectual collaboration with students. In our view, slow teaching is not about 'giving' students more time to read, think, explore and learn. It goes beyond a linear concept of time, time being understood and handled as a resource. Slow teaching focuses on being present, on the quality of attention enhanced by collective self-awareness and self-reflection." (Salo & Heikkinen, 2018)

The mathematician, philosopher and educator Mary Everest Boole (1832-1916) believed necessary a respectful silence by children in observing quietly the nature, accompanied by a deferential feeling (*homage*) in the face of the unknown, called *As-yet-Unknown Truth* (Magrone & Millán Gasca, 2018, p. 38). During the preparation for science "the reactions of amazement of the children let emerge the true depth: they hold their breath, for wonder and emotion" (Magrone & Millán Gasca, 2018, p. 161, auth. trans).
Science does not exclude a "poetic listening to nature" (Prigogine & Stengers, 1979/1993, p. 288, auth. trans): it requires a "new modality of amazement [...] in the double meaning of music and desire" which does not imply a privileged position of the experimental sciences (Stengers, 1979/1993, p. 90-91, auth. trans). But beware: in her most recent works on the Gaia crisis, Stengers writes that nature must not be thought of as something to be respected and defended, but as something "with which to compose" (Stengers, 2009/2021, auth. trans), indifferent to our reasons and our projects. According to her, the creative and destructive nature includes everything, even the anthropic element; however, Gaia will continue to exist even without us. This is why "talking about a fight against global warming is inappropriate; if it is a struggle, it is a struggle against what provoked Gaia, not against her response" (Stengers, 2009/2021, auth. trans). So, technological progress alone can only bring about a Pyrrhic victory. The philosopher adds:

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> "Don't ask me which «other world», capable of composing with Gaia, is possible. The answer does not belong to us: it belongs, rather, to a process of creation whose terrible difficulty would be senseless and dangerous to underestimate, but which would be suicidal to consider impossible at the same time. There will be no answer unless we have learned to hold both struggle and engagement within this process of creation, however hesitant and stuttering it may be." (Stengers, 2009/2021, auth. trans).

Reflections that stimulate deep thinking in students, beyond the dominant rhetoric about environmental problems.

14. Objectives achieved and invitation to further study

By these experiences, the students gained awareness of the value of urban/natural heritage and of its protection/enhancement. They certainly became aware that it is not enough to maintain a balance between urban areas and green areas, if the latter are not properly safeguarded (Figure 5). As, unfortunately, recent events have shown[xi], carelessness in the parks management causes indescribable damage to the natural heritage, especially for the role they play for the benefit of our cities.

Figure 5. Evocative image of the degraded state of the Pineto Park.

As explained during the meetings, soil is a non-renewable resource. The physical-chemical equilibrium, once compromised, is very difficult to restore: it takes years and huge financial commitments. The students explored the natural environment near their school, acquiring some basic knowledge of soil science, starting with soil sampling and performing simple chemical and physical analyses. The photographs and videos collected convey their awareness, the best result for educational projects of this kind.

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Furthermore, the students were able to appreciate the potential that GIS technology offers in preventing damages and proposing concrete actions to mitigate the negative effects of urbanisation advance. The so-called DDD (*Data-Driven Decision*) is the basis of geographic information systems - the use, processing and analysis of which guide scholars, researchers and administrators in decision-making (Giannola, 2013).
The students have understood the usefulness of the digital tools owned by everyone nowadays: mobile devices capable of communicating, documenting, analysing, transmitting contents; not simple "phones", but complete devices that allow anyone, via the network, to play an active role in understanding phenomena and proposing solutions. Sharing ideas is the extra weapon the current generation of students has to play a leading role.
The hope is that experiences like this will be repeated with increased levels of participation and involvement[xii], and will be an opportunity of orientation for further studies at university level. By now, courses on geographic information systems are activated in many faculties; they are: used for understanding and sharing information about economic phenomena, whose territorial impact is unquestionable; fundamental tools in geological and environmental analyses; irreplaceable systems in territorial, urban, landscape and natural heritage management. Last but not least, geographical information systems based on historical databases, the so-called Historical GIS, are becoming increasingly widespread: they can put historical cartographies into a system that reconstructs and disseminates the knowledge of a territory from an archaeological, geological, architectural and multicultural point of view (Grava et al., 2020).
The best ideas were selected by a panel of experts; Figure 6 shows the poster exhibited during the award ceremony at the University of Rome "Tor Vergata".
This educational project did not exclude the playful aspect and a conscious interaction with the natural environment; it is an example of how ecopedagogy and technology can be combined, according to a perspective that harmonises natural heritage and anthropic elements often unjustly demonised, especially in reference to synthetic chemistry.

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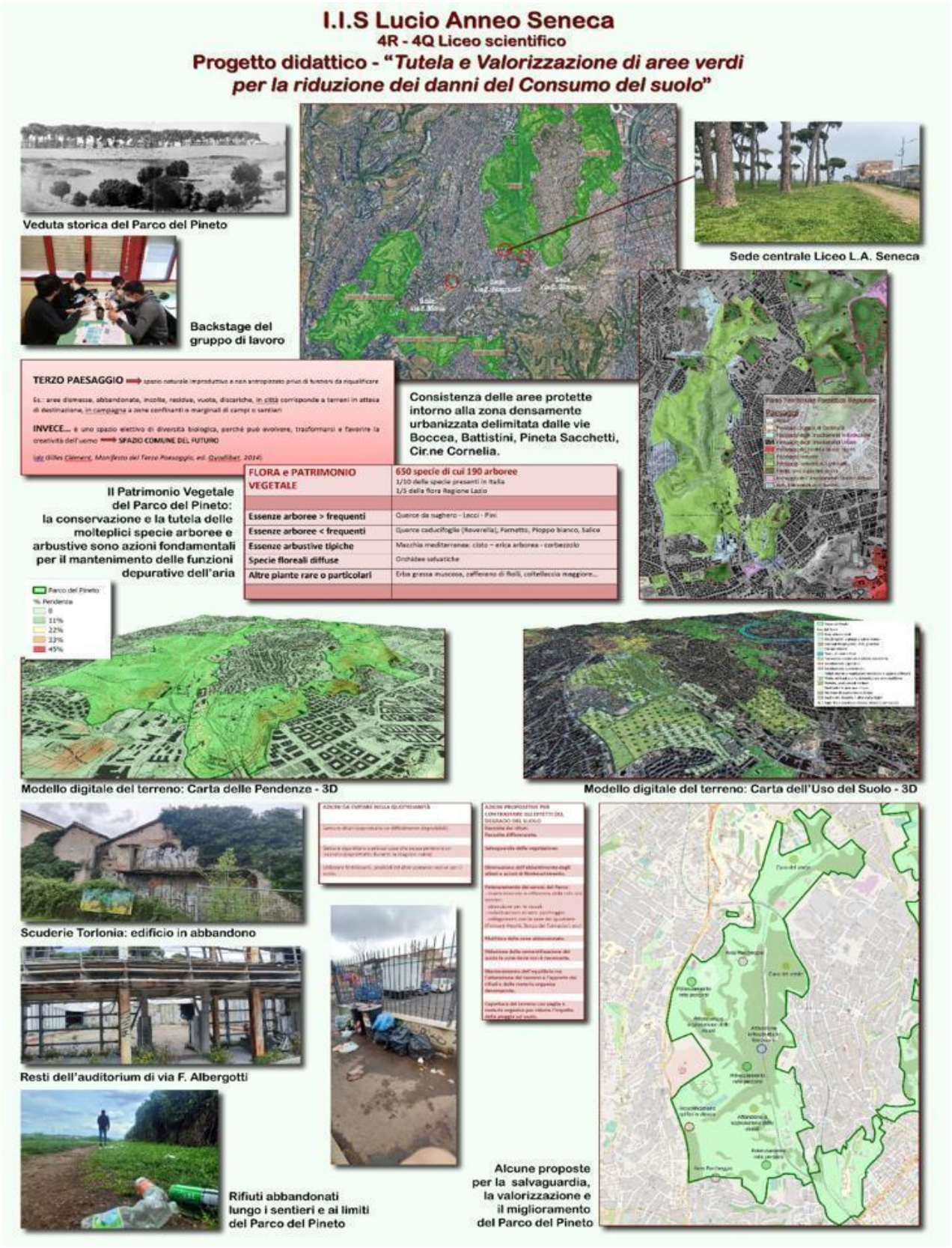

Figure 6. Poster of the award-winning teaching project at the "Tor Vergata" University.

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15. Future developments

Further developments include:
- enhancing the digital aspect through the creation of a virtual route within the Pineto Park, highlighting the natural beauty and the paths travelled by the students;
- developing simple schematisations and modelling of facts and phenomena;
- carrying out a tree census by Google Earth;
- refining the classification of the different soil types, further investigating the experimental aspects related to chemical and physical characteristics of the soil;
- storing soil samples (described by some chemical and physical indicators) in special containers at the disposal of the school;
- realising stratigraphic sections;
- identifying hydro-geological hazards in a more extended area in order to understand the related prevention activities.

All the results will be made available to other schools that want to give their contribution and to the local administration, in order to raise awareness among policy makers.

More generally, this project has tried to make a contribution in the sense indicated by Minello (2021): accumulate and disseminate knowledge on sustainability education; strengthen system-wide research skills oriented towards sustainability education; improve school systems through a research-based strategy of continuous optimisation of sustainability principles and initiatives. This requires synergistic actions by educators, researchers and policy makers. Continuous improvement will be slow, perhaps slower than the advancing socio-environmental problems, but the school cannot fail to do its part, from kindergartens to adult learning centres (Alessandrini et al., 2022).

16. Conclusion

The reflections presented in this work can be summarised as follows. Initially, the scope of the eco-pedagogical approach has been introduced: it offers opportunities for participatory sense-making and stimulates critical thinking, considering environmental emergency intimately connected to economic and social issues. Ecopedagogy is centred on love for the natural environment, but the concept of "natural" - in opposition to the concept of "artificial" - deserves some considerations: the students risk developing a Manichean vision of these two dimensions, nurturing stereotypes and prejudices. An example on soil erosion caused by urbanisation and synthetic chemicals has been considered; an idyllic vision of "nature" - which some currents of thought legitimise more or less covertly - has been criticised: chemistry and buildings play a fundamental role in our well-being that needs to be highlighted with conviction, also through some historical itineraries.

In a second time, some didactic, political and epistemic issues have been examined. In particular, this article warns against an instrumental use of ecopedagogy aimed at supporting neoliberal logics, which ecopedagogy itself wants to oppose.

A school project concerning the study of a historical park in Rome offered to students an opportunity for experiential and interdisciplinary learning, involving chemistry, geology and the use of geo-localisation tools. Starting from their study of Parco del Pineto, the students were led to reflect on the causes of degradation and the importance of technology in environmental policies, drawing up a mapping of the site and devising possible areas of intervention to be made available to local administrators. The final work was awarded in a university venue. Educators and students involved plan to continue this work, offering an example of how a local project

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can implement the cornerstones of the eco-pedagogical approach: love for the environment, observation and experience, critical thinking, collective responsibility for the shared environment - which includes making political claims and political action.

It was deemed appropriate to provide students with some food for thought, highlighting how scientific progress alone cannot resolve environmental problems: a change of consciousness, to which school communities are called, is required. "Slow research" and "slow teaching" can oppose the advance of neoliberal logic; unfortunately, the latter seems to permeate the fight against the environmental problems that it itself are contributing to exacerbate.

[i] The project activities were planned and implemented by Dora Stella Lombardi in cooperation with Stefano Merola.

[ii] Global Positioning System. The mobile devices available to students can lock onto the satellite network through the GPS antennas provided. Soon, thanks also to the spread of 5G technology, new networks will be made accessible, also due to lower prices and subscriptions. At present, the Lazio region is equipped with a GNSS (Global Navigation Satellite System) network that can reach centimetre-precision levels.

[iii] How many times have you accessed a TV platform, via a smart TV, when you have received a connection notification on your smartphone, or how many access your Wi-Fi remotely via geolocation services to connect to your home (home automation technology)!

[iv] Open Data identifies open-source data, which allows it to be used with non-proprietary software and applications, the availability of which on the web is increasing.

[v] A significant example of the use of geodata is the sharing of one's location or the location of a geographical place through the use of social networks.

[vi] Even in university curricula where only a few courses of study use GIS technology for the knowledge and analysis of spatial phenomena.

[vii] OpenStreetMap, Google Maps, Bing and Apple Maps are just a few examples. These databases can be combined with historical, environmental and economic databases, as well as with all those made available in free format by public and research organisations.

[viii] Pineto Park is in an extremely interesting location. Situated at a higher altitude than the city level, it enjoys a panoramic view of Rome and St Peter's Basilica. This makes it a place of extreme natural value (it is the green lung of a densely built-up area of Rome) as well as landscape value.

[ix] The CUS (in Italian: Carta dell'Uso del Suolo), at a scale 1:5,000, is the tool that the Lazio Region has made available since 2000 (updated in 2014) according to European specifications (in relation to the Corine Land Cover Project) for monitoring artificial, agricultural, wooded and wetland surfaces.

[x] The PTPR (in Italian: Piano Territoriale Paesistico Regionale) was approved by the Lazio Regional Council Resolution no.5 of 21 April 2021; it is the superordinate instrument appointed to regulate territorial and urban planning. Municipal Regulatory Plans must strictly respect the indications coming from Table A (Landscape Systems and Areas) and the constraints of Table B (Landscape Heritage).

[xi] We all remember the extended fire that broke out in the afternoon of 4 July 2022, between Pineta Sacchetti, Pineto Park and Monte Ciocci: about 300/350 hectares of the centuries-old pine forest and evergreen Mediterranean maquis were compromised, and 280 hectares were completely destroyed.

[xii] The pandemic has been and still remains, in this respect, a major obstacle.

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References

Alessandrini, G., Di Pinto, G., Giovanazzi, T., & Marcelli, A. M. (2022). Educating communities: From the epistemology of educational research to the case of adult learning centres in Italy. *Formazione & Insegnamento*, *20*, 966-975. https://doi.org/10.7346/-fei-XX-01-22_86

Anastas, P. T., & Warner, J. C. (1998). *Green chemistry: Theory and practice*. Oxford University Press.

Anastas, P. T. (2011). Twenty years of green chemistry. *Chemical & Engineering News*, *89*(26), 62-65. https://pubs.acs.org/cen/coverstory/89/8926cover6.html (accessed 07 March 2023).

Babini, V. P. (2020). Maria Montessori: una pedagogia dalla parte della vita. In B. Bianchi (Ed.), *DEP - Deportate, esili, profughe. Rivista telematica di studi sulla memoria femminile. Monographic Issue no. 44 - Ecopedagogy - In Memory of the Life and Work of Rachel Carson* (pp. 20-29). Ca' Foscari University. https://www.unive.it/pag/fileadmin/user_upload/dipartimenti/DSLCC/documenti/DEP/numeri/n44/file_unico_DEP_44.pdf (accessed 07 March 2023).

Bagheri, P., Gratchev, I., & Rybachuk, M. (2023). Effects of xanthan gum biopolymer on soil mechanical properties. *Applied Sciences, 13*(2), 887. https://doi.org/10.3390/app13020887

Baldacci, M. (2004). *Il problematicismo. Dalla filosofia dell'educazione alla pedagogia come scienza*. Milella.

Balzani, V. (2022). The cultural revolution: Ecological and social. *Substantia, 6(2)*, 5-6. https://doi.org/10.36253/Substantia-1741

Barbiero, G. (2011). Biophilia and Gaia. Two hypothesis for an affective ecology. *Journal of Biourbanism, 1*, 11-27

Barbiero, G. (2017). *Ecologia affettiva. Come trarre benessere fisico e mentale dal contatto con la natura*. Mondadori.

Bardulla, E. (1998). *Pedagogia ambiente società sostenibile*. Anicia.

Bartolini, S. (2021). *Ecologia della felicità*. Aboca.

Bauman, Z. (2017). *Paura liquida* [e-Book edition] (M. Cupellaro, Trans.). Laterza. (Original work published 2006)

Benasayag, M., & Schmit, G. (2003). *Les Passions Tristes. Souffrance psychique et crise sociale*. La Découverte.

Bianchi, B. (Ed.). (2020a). *DEP - Deportate, esili, profughe. Rivista telematica di studi sulla memoria femminile. Monographic Issue no. 44 - Ecopedagogy - In Memory of the Life and Work of Rachel Carson.* Ca' Foscari University. https://www.unive.it/pag/fileadmin/user_upload/dipartimenti/DSLCC/documenti/DEP/numeri/n44/file_unico_DEP_44.pdf (accessed 07 March 2023).

Bianchi, B. (2020b). Introduzione. In B. Bianchi (Ed.), *DEP - Deportate, esili, profughe. Rivista telematica di studi sulla memoria femminile. Monographic Issue no. 44 - Ecopedagogy - In Memory of the Life and Work of Rachel Carson* (pp. I-XVI). Ca' Foscari University. https://www.unive.it/pag/fileadmin/user_upload/dipartimenti/DSLCC/documenti/DEP/numeri/n44/file_unico_DEP_44.pdf (accessed 07 March 2023).

Biesta, G. (2005). Against learning. Reclaiming a language for education in an age of learning. *Nordisk Pedagogik*, *25*, 54-66.

Bishop, R. (2012). *Legacy of Rachel Carson's Silent Spring*. American Chemical Society. https://www.acs.org/content/dam/acsorg/education/whatischemistry/landmarks/rachel-carson-silent-spring/rachel-carsons-silent-spring-historical-resource.pdf (accessed 07 March 2023).

Bonaiuti, G., Calvani, A., & Ranieri, M. (2016). *Fondamenti di didattica. Teoria e prassi dei dispositivi formativi*. Carocci.

Cabrera, D., & Cabrera, L. (2015). *Systems thinking* [eBook edition]. Plectica.

Campanella, L., & Suffritti, P. (2021). Can non-recyclable plastic waste be made environmentally sustainable? *Substantia*, *5*(2), 35 - 39. https://doi.org/10.36253/Substantia-1287

Candiotto, L. (2022). Loving the earth by loving a place: A situated approach to the love of nature. *Constructivist Foundations, 17*(3), 179-189. https://constructivist.info/17/3/179

DOI: https://doi.org/10.6092/issn.1970-2221/16127

Capobianco, R., & Cerrato, M. (2022). Global citizenship education: The competencies of teachers to promote the 2030 agenda through civic education. *Formazione & Insegnamento*, *20*(2), 107-128. https://doi.org/10.7346/-fei-XX-02-22_08

Carra, J. (1999). International Diffusion of Sustainable Chemistry. In OECD Environment Directorate (Ed.), *Proceedings of the OECD Workshop on Sustainable Chemistry. Part 1* (pp. 47-50). OECD. https://one.oecd.org/document/ENV/JM/MONO(99)19/PART1/en/pdf (accessed 07 March 2023).

Carson, R. (1962). *Silent spring.* Houghton Mifflin.

Carson, R. (1998). *The Sense of wonder*. Harper Perennial (Original work published 1956)

Celestino, T. (2013). The ethics of green chemistry teaching. *Education in Chemistry, 50*(3), 24-25.

Celestino, T., & Marchetti, F. (2015). The chemistry of cat litter: Activities for high school students to evaluate a commercial product's properties and claims using the tools of chemistry. *Journal of Chemical Education*, *92*(8), 1359-1363. https://doi.org/10.1021/ed500505j

Celestino, T., & Marchetti, F. (2020). Surveying Italian and international baccalaureate teachers to compare their opinions on system concept and interdisciplinary approaches in chemistry education. *Journal of Chemical Education*, *97*(10), 3575–3587. https://doi.org/10.1021/acs.jchemed.9b00293

D'Alessio, C. (2021). Empatia ed intelligenza emotiva per una sostenibilità affettivo-sociale. Dalla teoria alla prassi. *Formazione & Insegnamento, 19*(1), 151-159. https://dx.doi.org/10.7346/-fei-XIX-01-21_12

De Jaegher, H., & Di Paolo, E. (2007). Participatory sense-making. An enactive approach to social cognition. *Phenomenology and the Cognitive Sciences*, *6*(4), 485-507. https://doi.org/10.1007/s11097-007-9076-9

Di Fabbio, A., & Fumanti, F. (2008). *Il suolo. La radice della vita*. APAT.

Domenici, V. (2022). Fake news in chemistry and how to deal with it. *Science in School*, *59*, 1-6.

Dozza, L. (2022). Ecology and education. *Formazione & Insegnamento*, *20*(3), 13-28. https://doi.org/10.7346/-fei-XX-03-22_02

Eni Scuola. (2022). *Suolo*. Retrieved online from: https://eniscuola.eni.com/assets/documents/ita/eniscuola/ambiente/terra/suolo/SUOLO.pdf (accessed 07 March 2023).

Espinosa-Corrales, D. M. (2021). *Disonancia cognitiva y constitución de sentido participativo en la toma de decisiones morales* [Master's thesis, Universidad de los Andes]. https://repositorio.uniandes.edu.co/bitstream/handle/1992/55441/26289.pdf?sequence=1&isAllowed=y (accessed 07 March 2023).

Essex, J., & Howes, L. (2014). Experiments in integrity - Fritz Haber and the ethics of chemistry. *Science in School*, *29*, 5-8

European Commission. (2006). *Strategia tematica per la protezione del suolo*, COM, 231, Bruxelles. Eur-lex.europa.eu. https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2006:0231:FIN:it:PDF (accessed 07 March 2023).

European Commission. (2018). *Final Report of the High-Level Panel of the European Decarbonisation Pathways Initiative*. Op.europa.eu. https://op.europa.eu/en/publication-detail/-/publication/226dea40-04d3-11e9-adde-01aa75ed71a1 (accessed 07 March 2023).

European Commission. (2019). *The European Green Deal*, COM, 640. Eur-lex.europa.eu. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52019DC0640 (accessed 07 March 2023).

European Commission. (2020a). *EU Biodiversity Strategy for 2030*, COM, 380. Eur-lex.europa.eu. https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1590574123338&uri=CELEX:52020DC0380 (accessed 07 March 2023).

European Commission. (2020b). *Farm to Fork Strategy. For a fair, healthy and environmentally-friendly food system.* Food.ec.europa.eu. https://food.ec.europa.eu/system/files/2020-05/f2f_action-plan_2020_strategy-info_en.pdf (accessed 07 March 2023).

DOI: https://doi.org/10.6092/issn.1970-2221/16127

Federchimica (2010). *Il ruolo della chimica nel sistema delle costruzioni*. Federchimica. https://www.federchimica.it/docs/default-source/saperne-industria/chimica_e_costruzioni167d1699284763c48ba4ff00009a7ece.pdf?sfvrsn=d93a7593_4 (accessed 07 March 2023).

Freire, P. (1973). *L'educazione come pratica della libertà*. Mondadori.

Gardner, H. (1999). *Intelligence reframed*. Basic Books.

Giannola, E. (2013). Il ruolo di Google Earth e OpenStreetMap nella partecipazione civica al processo decisionale. *Bollettino dell'Associazione Italiana di Cartografia*, *147*, 41-52.

Goleman, D. (2009). *Ecological intelligence: How knowing the hidden impacts of what we buy can change everything*. Broadway Business.

Grava, M., Berti, C., Gabellieri, N., & Gallia, A. (2020). *Historical GIS. Strumenti digitali per la geografia storica in Italia*. Trieste University Press.

Guerrini, E. (2019). *Percorsi didattici per lo studio delle discipline scientifiche*. Ed. Provincia Autonoma di Bolzano, Direzione Istruzione e Formazione Tedesca - Ripartizione pedagogica.

Higgins, P. (2002). Outdoor education in Scotland. *Journal of Adventure Education and Outdoor Learning, 2*(2), 149-168. https://doi.org/10.1080/14729670285200261

Hoffmann, R. (1995). *The same and not the same*. Columbia University Press.

Hofstein, A., Eilks, I., & Bybee, R. (2011). Societal issues and their importance for contemporary science education - A pedagogical justification and the state-of-the-art in Israel, Germany, and the USA. *International Journal of Science and Mathematics Education*, *9*, 1459-1483. https://doi.org/10.1007/s10763-010-9273-9

IEA. (2016). *Energy and Air Pollution – World Energy Outlook Special Repor*t. IEA Publications. https://www.iea.org/reports/energy-and-air-pollution (accessed 07 March 2023).

INFN. (2022). *Concorso scuole progetto SUSA 2022.* INF-LNF Educational. https://edu.lnf.infn.it/concorso-scuole-progetto-susa-2022/ (accessed 07 March 2023).

ISPRA. (2014). *Tematiche in Primo Piano - Annuario dei Dati Ambientali 2013.* ISPRA. https://www.isprambiente.gov.it/it/pubblicazioni/stato-dellambiente/tematiche-in-primo-piano-annuario-dei-dati-ambientali-2013 (accessed 07 March 2023).

ISPRA. (2021). *Libro bianco sulla gestione sostenibile dei suoli*. ISPRA. https://soil4life.eu/wp/wp-content/uploads/2022/02/libro-bianco-S4L-digitale-.pdf (accessed 07 March 2023).

Jeon, J. (2018). Green Chemistry. In *Encyclopaedia Britannica*. https://www.britannica.com/science/green-chemistry (accessed 07 March 2023).

Littledyke, M. (1997). Science education for environmental education? Primary teacher perspectives and practices. *British Educational Research Journal*, *23*, 641-659.

Lombardi, F.V. (2022). Pedagogia sociale e Urbanistica: strategie di intervento nelle realtà di periferia. *Orientamenti Pedagogici, 69*(4), 63-68.

Lopez-Cantero, P. (2022). Nature and the unlovable. *Constructivist Foundations, 17*(3), 208–209. https://constructivist.info/17/3/208

Luzzini, F. (2022). Preface. In D. Zampieri (ed.), *La valle dal cuore di perla* (pp. 13-19). Cleup.

Magrone, P., & Millán Gasca, A. (2018). *I bambini e il pensiero scientifico. Il lavoro di Mary Everest Boole.* Carocci.

Maher, M. (1986). What are we fighting for? *Geography Education*, *15*(2), 21-25.

Margiotta, U. (2012). Educazione e formazione dopo la crisi del welfare. In M. Baldacci, F. Frabboni, & U. Margiotta (Eds.), *Longlife/longwide learning. Per un trattato europeo della formazione* (17-42). Mondadori.

Margiotta, U. (2015). *Teoria della formazione. Ricostruire la pedagogia*. Roma.

Minello, R. (2021). Orizzonti della sostenibilità educativa: Tra trascendentalità e corporeità, virtualità e territorio. *Formazione & Insegnamento*, *19*(2), IX–X.

DOI: https://doi.org/10.6092/issn.1970-2221/16127

Molina, M. J., & Rowland, F. S. (1974). Stratospheric sink for chlorofluoromethanes: Chlorine atom-catalysed destruction of ozone. *Nature*, *249*, 810–812.

Montanari, T. (2014). *Istruzioni per l'uso del futuro. Il patrimonio culturale e la democrazia che verrà*. Minimum Fax.

Montessori, M. (2007). *Come educare il potenziale umano*. Garzanti. (Original work published 1947)

Norat, M. de los Á. V., Herrería, A. F., & Rodríguez, F. M. M. (2016). Ecopedagogy: A movement between critical dialogue and complexity: Proposal for a categories system. *Journal of Education for Sustainable Development*, *10*(1), 178-195. https://doi.org/10.1177/0973408215625552

OECD. (2018). *Pisa 2018 results*. Retrieved online from: https://www.oecd.org/pisa/publications/pisa-2018-results.htm (accessed 07 March 2023).

Papadimitriou, V. (2001). Science and environmental education: Can they really be integrated? In *Science and Technology Education: Preparing Future Citizens*. *Proceedings of the IOSTE Symposium in Southern Europe* (pp. 323-332). Imprinta Ltd. https://files.eric.ed.gov/fulltext/ED466366.pdf

Pavesi, A., & Dal Lago, M. (2021). Il Libro nella Giungla. Neoliberismo, comunitarismo e pedagogia reazionaria nell'educazione parentale e libertaria. *Materialismo Storico*, *11*(2), 342-357. https://doi.org/10.14276/2531-9582.3289

Pileri, P. (2015). *Che cosa c'è sotto.* Altreconomia Edizioni.

Prigogine, I., & Stengers, I. (1993). *La nuova alleanza. Metamorfosi della scienza* (P.D. Napolitani, Trans.). Einaudi (Original work published 1979)

Puleo, A. H. (2019). *Claves ecofeministas. Para Rebeldes que aman a la Tierra y a los animales*. Plaza y Valdés.

Radaelli, L., & Calamai, L. (2005). *Chimica del terreno*. Piccin.

Robottom, I., & Sauvé, L. (2003). Reflecting on participatory research in environmental education: Some issues for methodology. *Canadian Journal of Environmental Education*, *8*, 111-128.

Rollini, R., Falciola, L., & Tortorella, S. (2022). Chemophobia: A systematic review. *Tetrahedronthis, 113*, 132758. https://dx.doi.org/10.1016/j.tet.2022.132758

Salo, P., & Heikkinen, H. L. (2018). Slow science: Research and teaching for sustainable praxis. *Confero*, *6*(1), 87-111. https://doi.org/10.3384/confero.2001-4562.181130

Sauvé, L., & Godmaire, H. (2004). Environmental health education: A participatory holistic approach. *Ecohealth*, *1*, 35-46. https://doi.org/10.1007/s10393-004-0080-z

Sizmur, T. (2016). The ECG Interview: Tom Sizmur. *ECG Bulletin.* Royal Society of Chemistry. https://www.rsc.org/images/Bulletin-February-2016_tcm18-248132.pdf (accessed 07 March 2023).

Sjøberg, S., & Schreiner, C. (2010). *The Rose Project. An overview and key findings.* University of Oslo. http://roseproject.no/network/countries/norway/eng/nor-Sjoberg-Schreineroverview-2010.pdf (accessed 07 March 2023).

Spadafora, G. (2017). Possibili nuove tendenze della ricerca pedagogica nel dibattito culturale contemporaneo. *Nuova Secondaria Ricerca*, *9*, 36-46.

Stengers, I. (1993). *Le politiche della ragione* (C. Biasini & F. Giardini, Trans.). Laterza.

Stengers, I. (2018). *Another science is possible. A Manifesto for Slow Science* [eBook edition]. Polity. (Original work published 2013).

Stengers, I. (2021). *Nel tempo delle catastrofi. Resistere alla barbarie a venire* [eBook edition] (N. Manghi, Trans.). Rosenberg & Sellier. (Original work published 2009)

Strongoli, R. C. (2019). Ecodidattica. Una proposta di educazione ecologica. *Ricerche di Pedagogia e Didattica - Journal of Theories and Research in Education*, *14*(3), 221-243. https://doi.org/10.6092/issn.1970-2221/9890

DOI: https://doi.org/10.6092/issn.1970-2221/16127

Stumm, W., & Morgan, J. J. (1970). *Aquatic chemistry, chemical equilibria and rates in natural waters*. John Wiley and Sons, Inc.

Toadvine, T. (2011). Six myths of interdisciplinarity. *Thinking Nature*, *1*, 1-7

Tomarchio, M., La Rosa, V., & D'Aprile, G. (2019). *Natura Cultura. Paesaggi oltre confine dell'innovazione educativo-didattica*. Franco Angeli.

Tona, E. (2018). Paulo Freire precursore della pedagogia critica. *Formazione & Insegnamento*. *16*(2), 359-366

Tortorella, S., Zanelli, A., & Domenici, V. (2019). Chemistry beyond the book: Open learning and activities in non-formal environments to inspire passion and curiosity. *Substantia*, *3*(2), 39 - 47. https://doi.org/10.13128/Substantia-587

Varela, F. J., Thompson, E., & Rosch, E. (1991). *The embodied mind: Cognitive science and human experience*. MIT Press.

Wilson, E.O. (1993). *The biophilia hypothesis*. Island Press.

Zalasiewicz, J., Williams, M., Steffen, W., & Crutzen, P. (2010). The New World of the Anthropocene. *Environmental Science & Technology, 44,* 2228-2231. https://doi.org/10.1021/es903118j

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