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Geosciences didactic experiences as a key component in Education for Sustainable Development

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“Il più grande segno di successo per un insegnante è poter dire: i bambini stanno lavorando come se io non esistessi”
M. Montessori

“Education is the most powerful weapon which you can use to change the world”
Nelson Mandela

“*Education is not the filling of a pot but the lighting of a fire*”.
W.B. Yeats

“When one teaches, two learn”
R. Heinlein

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ABSTRACT

This research project aims to contribute to the dissemination of Agenda 2030 for Sustainable Development topics among pupils and all school communities. Since Geosciences intersect most of the Agenda 2030 Goals, Sustainable Development has become one of the core subjects of this discipline, as well as teaching Geoscience represents a key aspect of Education for Sustainability.

Several Geoscience topics, such as natural resources exploitation, responsible consumption, ecological and water footprint, circular economy and waste reduction are the main subjects addressed in this work. The choice of these research topics arises from both the many connections between Sustainability and everyday lifestyles and from their several linkages with different matters. This interdisciplinarity is in line with the Italian School Citizenship education guidelines about Sustainable Development and UNESCO key-competencies for Sustainability. In fact, Education for Sustainability is one of the three main components of Citizenship Education that has become mandatory for all Italian schools in the last two years. Moreover, the Italian School Department established that Citizenship Education has to be addressed using multidisciplinary approaches, involving all school's teachers.

For this reason and in order to support educators in developing interdisciplinary didactic pathways on Sustainability, I implemented some didactic activities with comprehensive ready-to-use tools that make them easily replicable. Moreover, starting from Geoscience educational experiences, like laboratorial activities about the water and ecological footprint topics, teachers could approach socio-economic issues both globally and locally with a contextualization in their own territory.

The study has been proposed with the dual purpose of spreading Earth Sciences topics among k6-k8 students and of using them as interdisciplinary vectors in order to promote eco-friendly behaviours. Understanding how to improve pupils' ability to establish and justify the relationships between humans and the environment is essential to make the younger generation become conscious and responsible towards the environment itself.

The topics developed in this research project are, in detail:

1- The ecological footprint and ecological rucksack of everyday life simple actions (like washing, eating, dressing…), with a special focus on natural resources exploitation (water, soil), waste production and the responsible actions of reducing, reusing, repairing and recycling. Team work and hands-on activities were carried out in order to improve students' awareness about these Sustainability subjects, linking them to pupils' real life.

2- Responsible food consumption and the ecological footprint of foods. Pupils were engaged in a team-challenge game, to discuss and think critically about the environmental impact of their daily diet, due to food production, transport, distribution and packaging. Topics like water, carbon and ecological footprint were developed, as well as agriculture and farming stress on our planet's health.

3- Agenda 2030 Goals (SDGs) and its call for immediate action towards responsible lifestyles. The several interconnections between Geosciences and the SDGs are deeply discussed with pupils and teachers, in order to highlight the key-role of this discipline in Education for Sustainability. Agenda 2030 is the core issue of all the activities realized for this research. Moreover, an educational game was developed, completely dedicated to this UN plan of action. It is a cardboard Game, called Sustainable City Game (S-City Game), planned in an interdisciplinary manner, that proposes topics related to Agenda 2030 and Sustainability (like SDGs and targets, circular economy, natural resources exploitation …). Several school matters, such as Science, Math, Geography, Technology, History and Citizenship were involved in this game. As a follow-up work, a digital version of the S-City Game was developed, in order to involve teachers and pupils from home, during COVID-19 lockdown.

Learning-by-doing, cooperative learning and learning-by-gaming are the methodological approaches used for the activities tested. In order to involve pupils in an active way and to make them think about simple responsible behaviours, manipulation, team-work and gaming have proven to be very useful educational tools to vehicle Sustainability topics.

The experimentation was carried out with k6-k8 students from different Italian schools. The first segment of the project was tested through activities in presence, while the second one was experimented through distance learning, because of the COVID-19 crisis. In fact, the activities in presence are based on practical and hands-on experiences, besides an educational cardboard game, called S-city game. As a follow-up work, the digital version of S-city game, included in a virtual environment, was implemented, in order to face the pandemic emergency that could stop the research experimentation. On the contrary, the use of virtual environments and digital gaming allowed us not only to reach students and teachers from different Italian regions, but also to obtain good results in terms of learning and satisfaction. Nevertheless the distance mode, the laboratorial didactic approach based on constructivism, continued to characterize this research.

Thanks to the data collected during this PhD project experimentation, we can positively evaluate the didactic activities tested that constitute effective educational pathways for improving pupils' awareness towards eco-friendly and responsible lifestyles.

The contents of this thesis are summarized below:

- *Chapter 1* contextualizes Sustainable Development as a core-issue in environmental education. Starting from the global environmental and social crisis and the road map towards the Agenda 2030 agreement, the main features of this plan of action are described. The several connections between Agenda 2030 Goals and Geosciences are explained, as well as how this discipline plays a fundamental role in addressing such topics. This chapter also explains how environmental education, according to UN and UNESCO guidelines, has been reoriented mostly towards Education for Sustainability in the last years.

- C*hapter 2* describes the theoretical framework about didactic approaches useful to address Education for Sustainability. This chapter reports how literature studies stress the urgent need to implement Education for Sustainability, using involving and multidisciplinary approaches. All the literature data suggest that constructivism and learning-by-doing approaches are effective tools to vehicle Sustainability topics.

- C*hapter 3* describes the methods, materials and tools used in this research project. More in detail are specified: all the steps of each activity, the objectives, times, targets and the educational materials used. The difference between the qualitative and quantitative analysis conducted is described too.

- C*hapter 4* reports the didactic activities created and the results achieved thanks to the investigations. A series of papers is included in this chapter, in order to describe specifically the results obtained by each activity tested. Finally, data collected through a qualitative analysis are reported.

-C*hapter 5* discusses the major results in the frame of the sector literature. The strengths of the project, but also the difficulties encountered, due especially to the COVID-19 pandemic are analyzed. Here a theoretical framework about distance learning is approached.

- C*hapter 6* is devoted to the conclusions, explaining how the main research project aims have been achieved. Implications of this research and ideas for future works conclude the chapter.

- *Chapter 7* contains references and sitography.

-*Annexes 1, 2, 3* contain data and operational sheets used in Activity A.

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1 - INTRODUCTION

1.1 Global issues

The actual global scenario led governments, scientists and society to face several environmental issues. In fact, global crises such as poverty, hunger, climate change, resources overexploitation, loss of biodiversity and environmental pollution increase are complex to face, and require a multilateral approach (Fig.1.1). The global community will have to contend with a number of significant challenges, including population growth, urbanization, climate change, competition for resources and changing dietary habits. The world's quest for dignity, peace, prosperity, justice, sustainability and an end to poverty has reached an unprecedented moment of urgency. In many different countries such issues cause instability and underline the extreme inequalities (Tafuni et al., 2019). No single individual will ever be able to solve them. Similarly, it is more and more apparent that no single nation or state will be able to ultimately protect its citizens from the negative consequences of these global challenges that call for a truly global response (Barth et al., 2021). Moreover, collective pro-environmental actions become necessary, engaging everybody in concerted actions. Many of the development paths of the industrialized nations are clearly unsustainable. And the development decisions of these countries, because of their great economic and political power, will have a profound impact on the world's future (WECD, 1987).

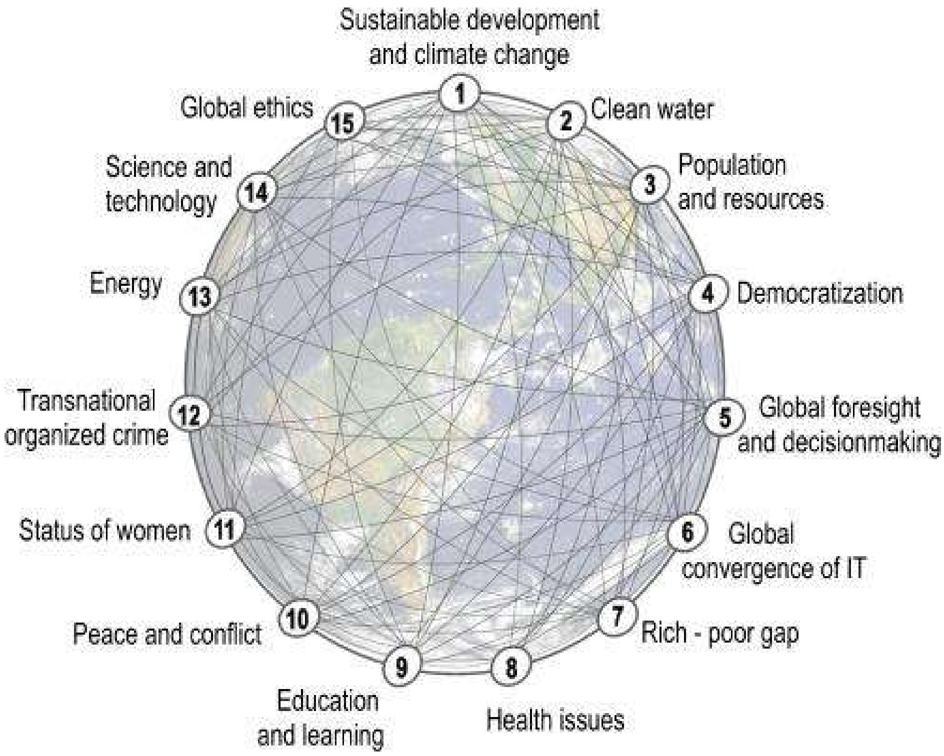

Fig. 1.1. Global issues are interconnected with each other.
(Source: http://www.millennium-project.org/projects/challenges/)

1.1.1 Poverty and hungry

One of the most urgent challenges is to fight poverty and hunger in all forms. The global Multidimensional Poverty Index (MPI) measures the complexities of poor people's lives, individually and collectively, each year. The MPI is an international measure of acute multidimensional poverty covering over 100 developing countries. It complements traditional monetary poverty measures by capturing the acute deprivations in health, education, and living standards that a person faces simultaneously. In "Poverty and Human Development Initiative" (Oxford, 2020) the 2020 MPI data are reported, highlighting that across 107 developing countries, 1.3 billion people (22 %) live in multidimensional poverty. Half of multidimensionally poor people (644 millions) are children under age 18. About 84.3 percent of multidimensionally poor people live in Sub-Saharan Africa (558 millions) and South Asia (530 millions). 84.2 % of multidimensionally poor people live in rural areas, where they are more vulnerable to environmental shocks (climate change and natural hazards e.g., earthquakes, volcanic eruptions, landslides and floods). More than 400 millions extremely poor people live in conflict areas, signaling the need to address poverty across the entire humanitarian and development continuum. It has been acknowledged that the objective of pulling people out of extreme poverty by 2030 will not be achieved without actions to reduce inequality, especially in natural resources access. High inequality is impeding further poverty reduction, and economic growth. The lack of progress in poverty reduction is apparent when considering poverty tout court: despite economic growth and a reduction in poverty, globally over 820 million people suffer from hunger (about one in every nine people in the world) and 2 billions people suffer micronutrient deficiencies (FAO, 2019).

The agriculture practices are often unsustainable and projections to 2050 suggest the emergence of growing scarcities of natural resources for agriculture, such as land and water (Alexandratos and Bruinsma, 2012). Meeting these challenges will require alternative choices for farmers to increase productivity on-farm, to shift to cultivations more resilient to climate change, while maintaining biodiversity and ecosystems services (Beddington, 2013).

Intensified competition for natural resources such as soil and water could lead to their increasing overexploitation and unsustainable use, degrading the environment and creating a destructive loop whereby resource degradation leads to ever increasing competition for the remaining available resources, triggering further degradation. In many low-rainfall areas of the The Middle East, North Africa and Central Asia, and in India and China, farmers use much of the available water resources, resulting in the serious depletion of rivers and aquifers.

1.1.2 Soil degradation

During 2015, the United Nations celebrated the International Year of Soils and a variety of FAO publications provide information on the status and aspects of soils in different environments (FAO, 2015). Healthy soils are the basis for healthy food production. Soils are the foundation for vegetation. They also play a main role in supporting biodiversity, combating and adapting to climate change and storing and filtering water. They are a nonrenewable resource, and a key to food security. Of the 11.5 billion ha of vegetated land on earth, around 24 percent has undergone human induced soil degradation. Land degradation costs an estimated $40 billion annually worldwide, without taking into account hidden costs of increased fertilizer use, loss of biodiversity and loss of unique landscapes (FAO, 2010). Degraded land is costly to reclaim and, if severely degraded, may no longer recover to provide the range of ecosystem functions and services that are critical for society and development (Foresight, 2011c). Adapting agriculture to be more resilient to the challenge of climate change, and competition for resources (land, water, and energy) will require investment in research to develop technologies, best practice and knowledge, which farmers can use to increase productivity, while maintaining biodiversity and ecosystem services.

1.1.3 Inequalities

As FAO declares (FAO, 2019), economic growth alone is not sufficient to reduce extreme poverty or improve food security and nutrition. Inequality, not only in the distribution of income, but also in access to natural resources, nutrition-relevant services and social and health infrastructure, is critical in understanding why this is so. In fact, evidence indicates that in countries that have greater levels of inequality, economic slowdowns and downturns have a disproportionately negative effect on food and nutrition security. Notably, several countries in Africa and Asia have seen large increases in income inequality over the last 15 years. The greater the inequality in asset distribution such as land, water, capital, finance, education and health, the more difficult it is for the poor to participate in economic growth processes. This then slows the progress in reducing food insecurity and malnutrition.

1.1.4 Global population growth

The world's population is projected to increase reaching 8.6 billion in 2030, and further to 9.8 billion in 2050 and 11.2 billion by 2100 (UN, 2017). Globally, more people live in urban areas than in rural areas, with 55 percent of the world's population residing in urban areas in 2018. Estimates and projections of urbanization introduced in the UN report (2018) indicate that the future growth of the human population can be accounted for almost entirely by a growing number of city dwellers. In 1950, 30% of the world's population was urban, and by 2050, 68% of the world's population is projected to be urban (UN, 2018) with nearly 90 per cent of the increase concentrated in Asia and Africa. Historically, the urban transition has been linked closely to economic development. In Europe and Northern America, rapid urbanization during the 19th and 20th centuries was accompanied by industrialization and rapid economic growth (Bairoch, 1988). Recent trends in developing regions, particularly in sub-Saharan Africa, have challenged long held notions about the association between urbanization and economic growth (Fay and Opal, 1999). While a dearth of data on urbanization in the region complicates any inference about trends (Satterthwaite, 2010), the available evidence suggests that the urbanization process continued in sub-Saharan Africa between the 1970s and 2000, despite economic contraction in the region over that period (United Nations, 2013).

1.1. 5 Urban population growth

Urban birth rates tend to be lower than urban death rates such that the urban population is sustained only by continuous replenishment through rural-to-urban migration. With improvements to public health, death rates begin to decline, faster in urban areas than in rural ones, and eventually the number of urban deaths falls below the number of urban births resulting in urban population growth caused not only by rural-to-urban migration, but also due to natural increase as well. In most regions, including in sub-Saharan Africa, the process of urbanization has occurred in parallel to declining mortality and fertility rates characteristic for the demographic transition, lending support to the notion that the urban transition is better explained as a demographic phenomenon than strictly as an economic one (Dyson, 2011).

The future of the world's population is urban. In many regions, the share of population living in cities, as well as the number and size of cities, will continue to grow, driven by a combination of factors, including a surplus of births over deaths in urban areas, migration from rural to urban areas and from abroad (Lerch, 2017) as well as the urbanization of formerly rural areas.The world's population growth to almost 10 billions by 2050, by some 50% compared to 2013 has to face a scenario of modest economic growth but increasing agricultural demand. Income growth in low- and middle-income countries would hasten a dietary transition towards higher consumption of meat, fruits and vegetables, relative to that of cereals, requiring commensurate shifts in output and adding pressure on natural resources. Satisfying increased demands on agriculture with existing farming practices is likely to lead to more intense competition for natural resources, increased greenhouse gas emissions, and further deforestation and land degradation (FAO, 2017). Resource-intensive farming systems, which have caused massive deforestation, water scarcities, soil depletion and high levels of greenhouse gas emissions, cannot deliver sustainable food and agricultural production.

1.1.6 Climate change

"Climate change is undeniable. Climate action is unstoppable. And climate solutions provide opportunities that are unmatchable." (Antonio Guterres, Secretary-General of the United Nations in 2017). The impacts of climate change are already being felt and – if left unabated – will intensify considerably in the years ahead. Global warming is expressed relative to the period 1850–1900, used as an approximation of pre-industrial temperatures. Warming refers to the estimated average temperature over the 30 years centred on that shorter period, accounting for the impact of any temperature fluctuations or trend within those 30 years. Globally integrated production processes have brought many benefits, but present challenges in terms of their regulation and the need to steer them towards more equitable and sustainable outcomes. The most recent assessment report of the Intergovernmental Panel on Climate Change (IPCC), published in 2014, levels of anthropogenic emissions of greenhouse gases (GHGs) are now at their highest in history (Porter et al., 2014). Changes due to global warming include increases in both land and ocean temperatures, in risk of drought in many regions as the Mediterranean one, as well as more frequent heatwaves and heavy precipitation events at the global scale. There are multiple lines of evidence that these issues have had impacts on organisms and ecosystems, as well as on human systems and well-being.

Agricultural production and farming and their effect on land use are major sources of these emissions. Charting environmentally sustainable pathways for agricultural development and food consumption has a central role to play, therefore, in mitigating climate change. The impacts of climate change are expected to be most adverse in low- and middle-income countries, where millions of people depend on agriculture and are vulnerable to food insecurity. In fact, in these areas, about 80 to 90% of water is used for agricultural purposes.

Climate adaptation refers to the actions taken to manage impacts of climate change by reducing vulnerability and exposure to its harmful effects and exploiting any potential benefits (IPCC, 2021). Adaptation takes place at international, national and local levels. Subnational jurisdictions and entities, including urban and rural municipalities, are key to developing and reinforcing measures for reducing weather- and climate-related risks. Adaptation implementation faces several barriers including lack of up-to-date and locally relevant information, lack of finance and technology and institutional constraints. Adaptation is more likely to contribute to sustainable development when both policies and social values and attitudes align with mitigation and poverty eradication goals.

Climate mitigation's goal, regarding international agreements (UN, 2015) is to limit global warming to well below 2, preferably to 1.5 degrees Celsius, compared to pre-industrial levels. To achieve this long-term temperature goal, countries aim to reach global peaking of greenhouse gas emissions as soon as possible to achieve a climate neutral world by mid-century. These mitigation actions are ambitious but indispensable. Pathways consistent with 1.5°C of warming above pre-industrial levels can be identified under a range of assumptions about economic growth, technology developments and lifestyles. However, lack of global and local cooperation, lack of governance of the required energy and land transformation, lack of responsible citizens' lifestyles, and increases in resource-intensive consumption are key impediments to achieving 1.5°C pathways (IPCC, 2021).

Avoiding impacts expected to occur by stopping global warming would also make it easier to achieve certain Sustainable Development Goals (Beg, 2011; Robinson, 2001), such as those that relate to poverty, hunger, health, water and sanitation, cities and ecosystems. In fact, compared to current conditions, climate change mitigation could contribute in a significant manner for eradicating poverty, reducing inequalities and ensuring human and ecosystem well- being.

Social justice and equity are core aspects of climate-resilient development pathways for transformational social change. Addressing challenges and widening opportunities between and within countries and communities would be necessary to achieve sustainable development and limit warming to 1.5°C, without making the poor and disadvantaged worse off.

1.1.7 Resources overexploitation

Each year the Global Footprint Network computes a day called "Earth Overshoot day". Earth Overshoot Day marks the date when humanity has used all the biological resources that Earth can renew during the entire year. Humanity currently uses 60% more than what can be renewed – or as much as if we lived on 1.6 planets (GFN, 2020) (Fig.1.2). Fig.1.3 shows the Global Ecological Footprint composition. Unsustainable consumption is one of the biggest contributors to our current and future environmental challenges: "as the world is consuming too much energy and materials to sustain itself" (UN, 2010).

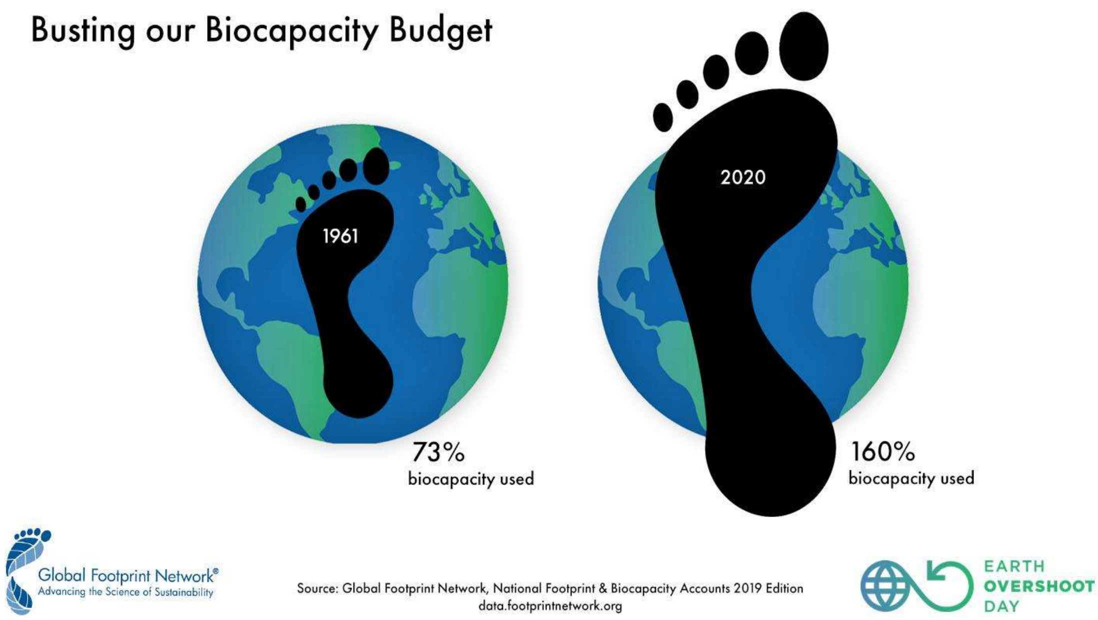

Fig. 1.2. Biocapacity used in 2020 compared with 1961.
(https://www.reteclima.it/overshoot-day-2020-alla-ricerca-di-nuovi-pianeti/)

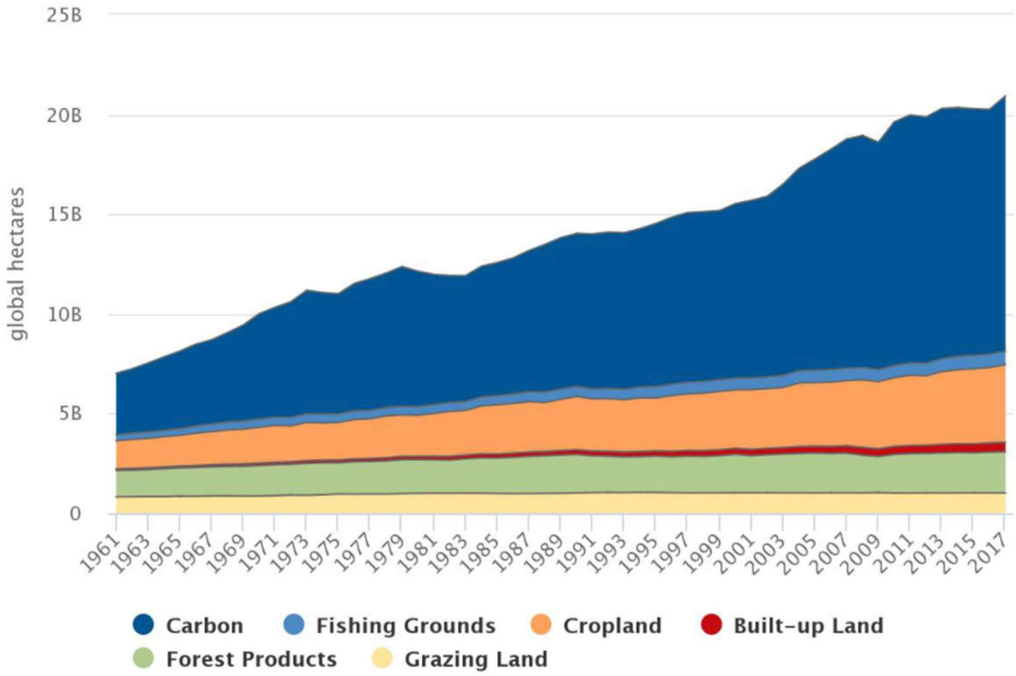

Fig.1.3. World ecological footprint by land type.
(https://www.footprintnetwork.org/)

The UN has calculated that due to population growth and the rise of consumers three Earths would be required by 2050 to fulfill the present-day consumption habits (UN, 2018). The Earth Overshoot Day 2020 lands exceptionally on August 22, more than three weeks later than in 2019, according to Global Footprint Network. The date reflects the 9.3% reduction of humanity's Ecological Footprint, which is a direct consequence of the Coronavirus-induced lockdowns around the world. Decreases in wood harvest and CO_2 emissions from fossil fuel combustion are the major drivers behind the historic shift in the long-term growth of humanity's Ecological Footprint. This fact demonstrated that shifting resource consumption patterns in a short time frame is possible. However, true sustainability that allows all to thrive on Earth can obviously be achieved by design, not disaster. Nevertheless, actual society is trapped in a consumerist and individualistic culture that encourages people to buy more and more for their own better lifestyle. Marketing sometimes deceives citizens to be free and powerful thanks to their purchase-power. But the reality is something different. Consumers are often slaves of capitalism because of the need to have the new: new clothes, new technological tools, new objects. Consumerism is based on people's infantilism that drives them to desire something different and additional to what they already have (Barber, 2007). Consumers sometimes feel fulfilled by meeting their needs and buying new goods. This scenario leads us to surmise that citizens are not sufficiently aware of the seriousness of the situation of our planet. Environmental problems such as deforestation, global warming and over-exploiting of fisheries, among others, are not sufficiently visible for the majority of citizens to change their habits of consumption. Therefore it can be affirmed that people are not fully aware of, nor committed to the true concept of sustainability, nor to the need to change the way of life and to conceive the world.

Young people are consumers and belong to a small consumers' community (family). The necessary change of mind among young people is to be free from marketing scenarios and learn to choose what they really need. The new challenge is the transformation of users' satisfaction. The challenge is to change the way of thinking as "*I shop, therefore I am*", into something like this: "*I choose to buy or not, therefore I am*". Education for Sustainability allows students to acquire knowledge about the ecological footprint of many goods, in order to become aware of consumerism's impact on the environment. Teachers and educators have the role to promote a transformation process in consumers' behaviour, beginning from the bottom (young people). This change of mind could be possible only if students understand the need for responsible natural resources management. Knowledge about ecological footprint, carbon footprint and water footprint of every good and food is necessary to build a new generation's responsible lifestyle. If only educators try to make pupils overcome the widespread belief that consumerism is a tool to achieve their own personal gratification, the transformation can occur.

1.1.8 Loss of biodiversity

The 2020 global Living Planet Index (WWF, 2020) shows an average 68% fall in monitored populations of mammals, birds, amphibians, reptiles and fish between 1970 and 2016. Species' population trends are important because they are a measure of overall ecosystem health. The most important direct driver of biodiversity loss in terrestrial systems in the last several decades has been land-use change, primarily the conversion of pristine native habitats into agricultural systems; while much of the oceans have been overfished. Globally, climate change has not been the most important driver of the loss of biodiversity to date, yet in the coming decades it is projected to become as, or more, important than the other drivers. The loss of biodiversity is not only an environmental issue but a development, economic, global security, ethical and moral one. It is also a self-preservation issue. Biodiversity plays a critical role in providing food, fibre, water, energy, medicines and other genetic materials; and is key to the regulation of our climate, water quality, pollution, pollination services, flood control and storm surges. In addition, nature underpins all dimensions of human health and contributes on non-material levels – inspiration and learning, physical and psychological experiences and shaping our identities – that are central in quality of life and cultural integrity.

1.1.9 Conflicts

Several conflicts around the world are caused by poverty and denied access to natural resources. Conflicts in rural areas, especially civil conflicts, can heavily affect agricultural production and livelihoods (Center for Systemic Peace, 2012). Vulnerable people and at-risk communities lose access to the range of resources necessary for food and agriculture production, through the seizure of natural resources and displacement from land, homes, fishing grounds and grazing areas. Denials of access, as well as the destruction of food stocks, which are increasingly used as tactics of war, are in direct violation of international humanitarian and human rights laws. Countries with the highest levels of undernourishment tend to be those engaged in, or recently emerged from, violent conflict. High risk of conflicts is a key characteristic of 'fragile states', and the prevalence of hunger rises exponentially with the degree of fragility, and vice-versa. Violent conflict also frequently characterizes protracted crises, in which a significant proportion of the population is acutely vulnerable to death, disease and disruption of livelihoods over a prolonged period of time. As of 2014, approximately 60 million people were displaced, due to conflicts in countries such as Somalia, Iraq, Syria, Nigeria, South Sudan, and Ukraine (United Nations, 2015b). Many armed conflicts have been resolved, but new ones have emerged.

1.1.10 Waste

Owing to the unprecedented growing population, economic prosperity and scientific and technological advancements in the 21st century, the world is experiencing a massive volume of waste materials discarded from industrial processes, domestic disposal systems and end-of-life devices (Sahajwalla, 2020). The efficient and timely management and reduction of waste materials are critical owing to potential risks for the environment and human health. On the other hand, almost all solid waste materials include resources that can be processed for different applications with far less spent energy compared with virgin materials. This potential drives us to find solutions for reusing, recycling, and recovery of solid waste materials, instead of landfilling and incineration, which are dominant current approaches.

Solid electronic waste (e-waste) is another issue in the modern world due to the widespread consumption habits of buying more and more new products. According to the United Nations', we can talk about the fastest growing e-waste stream as a 'tsunami of e-waste'. In fact, almost 50 million tonnes per year is the current rate of globally produced e-waste which is projected to be 120 million tonnes by 2050. While discarding electronic devices which causes environmental impacts, health problems, and resource depletion are one side of the problem, aligning the waste stream based on Sustainable Development Goals can offer scientific, technological, and economic opportunities. Regarding the circular economy, e-waste which includes invaluable precious minerals, metals, polymers and ceramics can be recycled and recovered for other purposes, leading to a substantial drop in CO_2 emission compared with mining processes. What makes e-waste, particularly wastes printed circuit boards (WPCBs), batteries, and mobile phones, more attractive is the value of the entangled metals, including Cu, Fe, Al, Ni, Mn, Ag and Au. However, from scientific and engineering viewpoint, high-efficiency sustainable recycling of e-waste is a challenging issue due to the complex nature and heterogeneity of electronic materials (e.g., composites, hazardous substances, heavy metals, and so on.) and using toxic chemicals in recycling processes (Nekouei, 2020).

1.1.11 The perfect storm: a global collapse due to consumerism

In the context of climate change, the increasing population and levels of urbanisation, the increasing natural resources overexploitation and waste production, pollution, the lack of clean water, soil degradation, loss of biodiversity, along with the urgent concern of fighting poverty and hunger, are likely to lead to a global collapse. This risk has been called "*the Perfect Storm*" by Professor Sir John Beddington (Senior Adviser at the Oxford Martin School and Professor of Natural Resources Management at the University of Oxford). According to Beddington (2009), projections suggest that by 2030 demand for food, water, and energy will increase by 40 percent, 30 percent and 40 percent respectively (FAO, 2010; OECD, 2008). Currently, 1.2 billion people live in areas affected by physical water scarcity, 1.6 billion people live in areas affected by economic water scarcity, and 884 million people lack access to clean water. Currently, 1.4 billion people do not have sufficient electricity, and it is estimated that by 2030, 1.2 billion people will still lack access to electricity. The global population growth will increase food (especially meat), energy and other natural resources demand and consumption, with the consequence of goods demand and production increase. This consumption is not distributed uniformly across all nations, with some countries likely to be using significantly more of these resources than others. An increasing demand for other materials, including minerals, is being driven by population growth and a growing middle class (Lambert et al., 2013), but also by overconsumption in many places. To fully comprehend current development challenges, the lack of access to resources in some parts of the world needs to be contrasted with overconsumption in other parts of the world. At the same time, systems will be needed to encourage private enterprise, and to strengthen access to markets (Beddington, 2013). But the real problem to face nowaday is the "*end of everything*", overcoming the false illusion that Earth could be endless (Giovannini, 2018).

The "Perfect storm" represents both a global crisis alarm and an invitation for action immediately. On the occasion of the 3rd Nobel Laureate Symposium on Global Sustainability (Stockholm,2011) Nobel Laureates and experts on sustainability gathered and raised an alarm for people and planet and a global transition towards sustainability. Experts discussed science data that show how human activities pressure on the Earth overcomes the capacity of our planet to absorb such impact. This critical issue needs both short-term urgent solutions (environment and social equity) and long-term solutions (re-construction of social value, institutions and way of thinking). On the occasion of that Symposium the question discussed by experts was: "Can we innovate sufficiently rapidly and with sufficient intelligence to transform our system out of a destructive pathway and into one that leads to long-term social and ecological resilience?" Resilience issue has been introduced as "the capacity of a system to absorb disturbance and reorganize while undergoing change, so as to still retain essentially the same function, structure, identity, and feedbacks" (Walker et al. 2004; Folke et al. 2010). Transformability means "the capacity to create untried beginnings from which to evolve a fundamentally new way of living when existing ecological, economic, and social conditions make the current system untenable" (Walker et al., 2004; Chapin et al., 2010; Folke et al., 2010, 2011). A complex system perspective recognizes the dynamic links between the social, ecological, and technological subsystems is needed to understand the paradox of innovation:

innovation is both a contributing cause for our current unsustainable trajectory but also the hope for tipping in new more resilient directions.

But how could we measure and evaluate the state of global crises and the progressive steps towards a global transformation and people's quality improvement? For a longti me statistical data such as Gross Domestic Product (Gdp) and the percentage of employed people have been the most relevant indexes to measure people's well-being. Nevertheless, in the last two decades, governments ought to reconsider the countries' progress measurement in order to embrace the sustainability pathway, going beyond the assessment only of GdP. The "GDP and beyond" roadmap adopted in 2009 (EU commission, 2009) aims to complement GDP with high level indicators reflecting issues such as environmental protection, quality of life and social cohesion. In the 21th century OCSE countries started to devote international discussions about society progress, showing a change of mind desire among politicians (Comin, Speroni, 2012). Statistic experts, psychologists, politicians and economists began to agree to integrate the well-being of the country with the social dimension, considering several indicators for societal progress beyond only the GDP measurement. Enrico Giovannini, a famous economist and statistician (2001 OCSE Chief Statistician), and "Alleanza italiana per lo sviluppo sostenibile" (ASVIS) spokesman has been one of the promoters of this change of mind. While GDP and employment rate as concepts remain indispensable, there are still areas in which improvements in measurement are required such as quality of life and sustainability (German and French Economic councils, 2010). Human well-being embraces not only economic growth, but also improvement in education, human and environmental health, biodiversity, security, political voice, social connections and relationships, personal economic security (quality of life) and resources and energy responsible consumption (sustainability). In addition, today new elements are more often considered by economists, psychologists and philosophers: happiness and resilience. Happiness is considered as satisfaction for one's own life in all aspects and resilience as the potential to positively react to a shock (Sustainable Development Networks, 2017). Therefore, Sustainable Development links all these economic, environmental and social dimensions.

1.2 Transforming our world: the 2030 Agenda for Sustainable Development

1.2.1 The road towards Sustainability

Despite the recent introduction of Sustainable Development in school curricula, it is not a new topic for scientists, environmentalists and politicians. In fact, in the most recent international agreement for Sustainability, the new UN Agenda 2030 (2015), UN member States reaffirm the outcomes of all major United Nations conferences and summits which have laid a solid foundation for Sustainable Development and have helped to shape the new plan of action.

The road towards Sustainability has a series of steps over the years, since environmental and social dimensions have become key-issues in global development (Fig. 1.4). The term "Sustainability" was first coined by the World Conservation Strategy (IUCN/UNEP/WWF, 1980) which gave fluency to the term 'Sustainable Development', as the way to protect essential ecological processes, life-support systems and genetic diversity, as well as the sustainable utilisation of natural resources. Most significantly, the Strategy linked topics as economic growth, environmental preservation, poverty, development and described the dilemma of rural people in some developing countries destroying natural resources in order to free themselves from starvation and poverty. In the report, education is seen as playing a key role in remedying such matters.

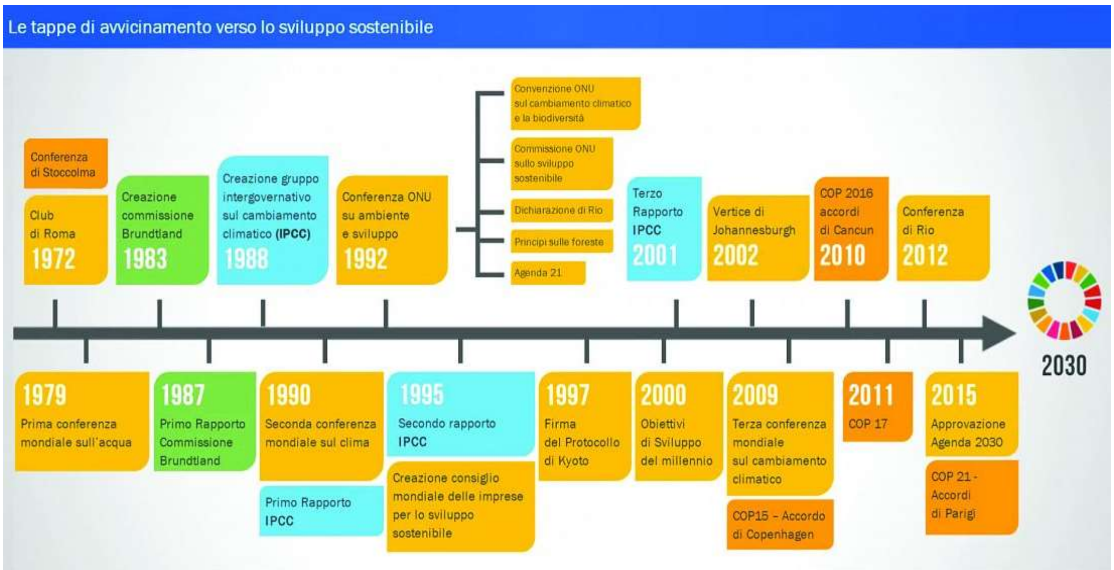

Fig. 1.4. The road towards Sustainability.

"Utopia sostenibile"- Enrico Giovannini, ed. Laterza, 2018)

“Sustainability” was later reinforced in 1980 by the Brundtland Report (World Commission on Environment and Development, WECD) refers to: (a) the need for reconciliation between economic development and environmental protection; (b) the need to place any understanding of environmental concerns within a socio economic and political context; (c) the need to combine environment and development issues. Moreover, the Brundtland Report first gave a definition for Sustainable Development: “ *the sustainable development is the development that meets the needs of the present without compromising the ability of future generations to meet their own...extending to all the opportunity to satisfy their aspirations for a better life... by increasing productive potential and by ensuring equitable opportunities for all...Since that expansion in numbers can increase the pressure on resources and resources are not renewable,... sustainable development is a process of change in which the exploitation of resources are in harmony with our planet and enhance both current and future potential to meet human needs and aspirations… Since development tends to simplify ecosystems and to reduce their diversity of species, and species, once extinct, are not renewable... sustainable development requires the conservation of plant and animal species* “. The Brundtland Report strengthened the linkage between the environment dimension and human actions, ambitions, and needs: “ *the environment is where we all live; and "development" is what we all do in attempting to improve our lot within that abode, the two are inseparable*”. The Agenda 2030 is a plan of action that puts foundation on the purposes and guidelines of several international agreements. First, the principles of the Charter of the United Nations (1945), including full respect for international law, sovereign equality of States and the prohibition of the use of force in international relations. It is grounded by the Universal Declaration of Human Rights (1948), the Rio Declaration on Environment and Development (1992), the Agenda 21 by United Nations Conference on Environment and Development (1992), the Programme of Action of the International Conference on Population and Development (1994), the World Summit for Social Development (1995), the Millennium Declaration (2000), the World Summit on Sustainable Development (2002), the World Summit Outcome (2005).

Principle One of the Rio Declaration states that "*Human beings are at the center of concerns for sustainable development. They are entitled to a healthy and productive life in harmony with nature*" (UN, 1992 a). The Rio Declaration strongly highlights the interconnection between social and environmental dimensions. The Agenda 21 stresses the need to save human well-being and protect the environment.

The Agenda 21 calls humanity to face a defining moment in history, because of a perpetuation of disparities between and within nations, a worsening of poverty, hunger, ill health and illiteracy, and the continuing deterioration of the ecosystems on which humanity depends for well-being. Integration of environment and development concerns and greater attention to them is a key issue in this document, in order to achieve the fulfillment of basic needs, improved living standards for all, better protected and managed ecosystems and a safer, more prosperous future. The Agenda 21 calls nations to cooperate because no one can achieve this on its own, "*but together we can - in a global partnership for sustainable development*" (UN, 1992 b). All the Agenda 21 section 2 deals with conservation and management of natural resources. The call for a global partnership to reach Sustainable Development will become one of the Agenda 2030 Goals (Goal 17). The Millennium Declaration (UN, 2000) committed nations to a new global partnership to reduce extreme poverty, and set out a series of eight time-bound targets - with a deadline of 2015 - that have become known as the Millennium Development Goals (MDGs). The MDGs represent a call for action that will follow in the next Sustainable Development Goals, aiming to fight extreme poverty and hunger, achieve universal primary education, promote health and gender equality and ensure environmental sustainability. The MDGs helped spur advances on many fronts. In health, the MDGs have been associated with a significant acceleration of progress in some of the poorest countries (You, 2015) and the maternal mortality ratio has reduced by 36% when contrasting figures from 2000 and 2015 (United Nations, 2015).

In education, there are almost half as many out-of-school children of primary school age. Regarding drinking water access, it has increased from 76% of the global population in 1990 to 91% of the global population in 2015, with 73% of this increase being through piped water to premises (United Nations, 2015). The water supply remains a global relevant issue that needs urgent actions (Mc Arthur, 2017). On the contrary, a lack of progress on environmental sustainability was observed under the three Rio Conventions (Tollefson, 2012). The MDGs on reducing poverty have been met by many countries and, globally, the number of extreme poor has fallen by over 50%, yet many countries lag behind (e.g.Sub-Saharan Africa), reporting insufficient progress or deterioration. In fact, in 2015 the numbers of poor people remained high: almost one billion people are considered extremely poor and another billion poor. Example statistics from the United Nations (2015) show that, with respect to the population of sub-Saharan Africa: 70% are not using improved sanitation facilities; 32% lack access to an improved water source; 23% are undernourished; 41% live on less than $1.25 a day. Similar issues persist also in other countries, such as Southern Asia. Therefore, the post-2015 challenge became the full eradication of poverty and hunger (FAO, 2015).

<u>1.2.2 The Agenda 2030: a plan of action towards 2030.</u>

The Agenda 2030 for Sustainable Development (UN, 2015) is a plan of action that aims to promote global peace and achieve the Sustainable Development already defined by the Brundtland Report (Fig. 1.5). Th Agenda 2030 is a historic decision on a comprehensive, far-reaching and people-centered set of universal and transformative Goals and Targets. The Agenda 2030 and its 17 Sustainable Development Goals (SDGs) and 169 Targets seek to build on the Millennium Development Goals and complete what they did not achieve. The SDGs framework focuses on people, planet, prosperity, peace, and partnership whose interlinkages or integrated nature are key to realizing the Agenda (Fig. 1.6).

Fig.1.5. “Transforming our world: the Agenda 2030 for sustainable development”. (https://www.un.org/sustainabledevelopment/development-agenda/)

Fig. 1.6. The 5 P dimensions of Sustainability.
(https://www.unescap.org)

The Goals and targets are the result of over two years of intensive public consultation and engagement with civil society and other stakeholders around the world which paid particular attention to the voices of the poorest and most vulnerable. This consultation included valuable work done by the Open Working Group Of the General Assembly whose Secretary General provided a synthesis report in December 2014. The United Nations summit for the adoption of the Agenda 2030 was held from 25 to 27 September 2015, in New York, convened as a high-level plenary meeting of the General Assembly, on the occasion of the seventieth UN anniversary. The Agenda 2030 entitled “Transforming our world” was agreed by all 193 member states of the United Nations. This plan of action, complemented by commitments made in the Paris Agreement maps out a broad spectrum of economic, social and environmental objectives to be achieved by 2030.

An extract from the preamble follows: “*This Agenda is a plan of action for people, planet and prosperity. It also seeks to strengthen universal peace in larger freedom. We recognize that eradicating poverty in all its forms and dimensions, including extreme poverty, is the greatest global challenge and an indispensable requirement for sustainable development. All countries and all stakeholders, acting in collaborative partnership, will implement this plan. We are resolved to free the human race from the tyranny of poverty and want to heal and secure our planet. We are* *determined to take the bold and transformative steps which are urgently needed to shift the world on to a sustainable and resilient path. As we embark on this collective journey, we pledge that no one will be left behind*" (UN, 2015).

Analyzing this preamble, the first need for achieving global peace is to urgently fight extreme poverty and hunger. This challenge requires the planet's protection from degradation, including sustainable consumption and production, sustainably managing natural resources and taking urgent action on climate change in order to support the needs of present and future generations. The end of poverty and hunger, in all its forms and dimensions, ensures that all human beings can fulfill their potential in dignity and equality in a healthy environment, in harmony with nature. The UN member states declared to be determined to foster peaceful and just ensuring inclusive societies free from violence and fear, thanks to a more sustainable world. "There can be no sustainable development without peace and no peace without sustainable development" (UN, 2015). Moreover, UN States agreed to voluntary and country-led efforts to monitor and work toward achieving the SDGs. The United Nations have to mobilize the means required to implement this Agenda through a revitalized Global Partnership for Sustainable Development, based on a spirit of strengthened global solidarity, focused in particular on the needs of the poorest and most vulnerable and with the participation of all countries, all stakeholders and all people. The SDG framework interlinks human well-being with environmental topics. "No one will be left behind", especially the poorest countries that are the most affected by environmental issues such as climate change, natural disaster and natural resources overexploitation.

The SDGs framework and means of implementation are thought as universal, indivisible, and interlinked (Fig.1.7). Moreover, they balance the three dimensions of Sustainable Development: the economic, social and environmental (Fig.1.8).

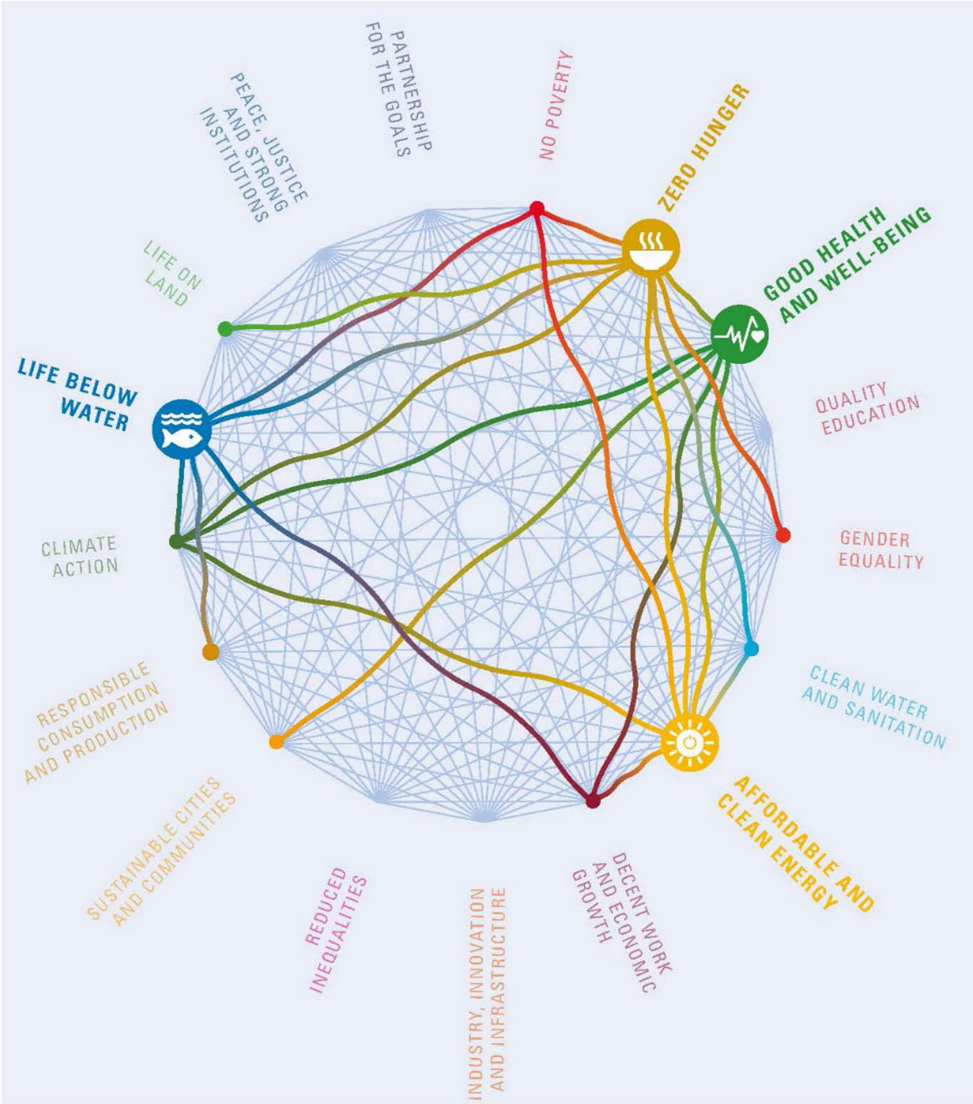

Fig. 1.7. Interlinkages among SDGs.
(https://www.greenbiz.com/article/sdgs-everything-connected)

Fig. 1.8. Integration of the three dimensions of Sustainable Development. (https://www.unescap.org)

The new vision of shared prosperity opens the way to a sustainable consumption of georesources, overcoming the inequality in their global distribution. “*We envisage a world in which consumption and production patterns and use of all natural resources -from air to land, from rivers, lakes and aquifers to oceans and seas are sustainable*” (UN, 2015). For all these aims, good governance plays an essential role to achieve sustained and inclusive economic growth, social development, environmental protection and the eradication of poverty and hunger. The application and improvement of technology has to be climate-sensitive, respecting the environment and biodiversity: “we envisage a world in which humanity lives in harmony with nature and in which wildlife and other living species are protected”, (UN, 2015). Therefore, the Agenda 2030 unique features are: universality, the call for a shared participation in change (no left one behind), the holistic vision of global issues and of the actions to take for achieving sustainability. All the countries ought to give their contribution on Sustainable Development, without distinction between developed and developing countries. A decisive contribution must come from the bottom. In fact, all of society is called to act: government policy, institutions but also the individuals who have an important role as customers, users, voters and educators. Education has long been recognized as a critical factor in addressing environmental and sustainability issues and ensuring human well-being (UNESCO, 2016). In fact, in each set of targets, at least one involves learning, training, educating or at least raising awareness of core Sustainable Development issues.

1.2.3 The Sustainable Development Goals (SDGs)

The organization of the 17 SDGs—which have assigned numbers but not explicit rankings in terms of importance—presents an opportunity to see issues as mutually dependent upon one another for their achievement. To offer an example, one cannot effectively address poverty (Goal 1) without also addressing access to clean energy (Goal 6), gender equality (Goal 5), action for climate (Goal 13), responsible consumption and production (Goal 12). Assigning the SDGs different numbers separates the Goals into distinct issues that can be examined individually and in-depth; but when seen as a whole set, the Goals invite a holistic, integrated perspective.

SDG 12 (sustainable consumption and production) suggests the right way towards an overcoming of consumerism. People, starting from young, have to be educated on the ecological footprint of daily-use goods and everyday life actions. They could become aware about the big amount of natural resources and carbon emissions behind daily-routine actions and consumption. Furthermore, Rees (1992) suggests that expanding the ‘economic pie’ to include the most dispossessed, will necessarily include even more natural resources being consumed. Since the material saturation level as witnessed by western consumers is ‘unsustainable’, the negative spiral of increasing needs for resources and depletion is not likely to cease. The oxymoronic goal of both promoting development through economic growth, redistribution of wealth and keeping the health of the ecosystem intact, the internalization of the ideas of ‘development’ poses new ethical challenges (Shoreman-Ouimet & Kopnina. 2011).

Furthermore, the consumerism issue is strictly connected with a waste increase whose management is an urgent challenge to face, but solutions are possible and something could be done. First, the transition from linear to circular economy that involves society at all. In the production-consumption process it is necessary to “close the loop”, saving resources. Processes such as recycling, resource recovery, urban and landfill mining, waste minimisation and material recovery and concepts such as the circular economy, eco-design, ecological footprinting and zero waste are terms that are being increasingly used by politicians, industrialists and businesses. This signifies that society is starting to catch up with the waste and resource management community in recognising that the resources which are contained in wastes should be recovered and utilised as much as possible. There are multiple reasons for this significant moment, including: concern about increasing global consumption of non-renewable resources, progressive shortages of primary raw materials, reduction of space available for final disposal of wastes, the need for quantity and volume reduction of wastes generated, the need for control of environmental contamination caused by emissions from waste treatment, changing social attitudes towards waste management, etc. (Cossu & Williams, 2015).

Landfill Mining represents the activities involved in extracting and processing wastes which have been previously stocked in particular kinds of deposits (municipal landfills, mine tailings, etc.).

Urban Mining extends landfill mining to the process of reclaiming compounds and elements from any kind of anthropogenic stocks, including buildings, infrastructure, industries, products (in and out of use), environmental media receiving anthropogenic emissions (Baccini and Brunner, 2012; Lederer et al., 2014). The stocked materials may represent a significant source of resources, with concentrations of elements often comparable to or exceeding natural stocks. As for natural ores, extraction and processing of anthropogenic stocks is necessary and the generation of an economic benefit is essential. For these reasons, urban mining originally focused on electrical and electronic wastes (WEEE) which contain relatively high concentrations of expensive metals and rare earth elements.

Resource Recovery includes the energy that can be generated by treating and managing wastes as well as materials recycling.

Materials Recycling aims to transform selected wastes into materials that can be used in the manufacture of new products. Packaging waste (plastics, paper, cans, glass), putrescibles, bottom ash, sewage, exhausted oils, scrap tyres, WEEE (or e-waste), end-of life vehicles etc., are waste flows commonly considered as falling within material recycling strategies. The recovered materials after processing (not necessarily implying an extraction process) are reintroduced in production cycles.

Whilst from an etymological point of view, it is clear that urban mining should refer to the exploitation of anthropogenic stocks, today the term is widely used for describing almost any sort of material recycling (Fig. 1.9).

Fig.1.9. Connections between urban mining, resource recovery and materials recycling. (Cossu & Williams, 2015)

If these activities' responsibility are of companies and municipalities, the first challenge is on citizens' hands. In fact, actions such as reducing consumption, reusing and repairing objects are the first steps in transition towards sustainability and saving resources. For this aim, Agenda 2030 calls for action citizens in first actions. SDG11 is the evidence.

SDG 11 (sustainable cities and communities) is a commitment to making cities inclusive, safe, resilient and sustainable, and participatory planning can play an important role in the implementation. SDG 11 stresses that urbanization is closely related to the three dimensions of Sustainable Development: economic, societal and environmental. Well-managed urbanization (among other factors), informed by an understanding of population trends over the long run, can help to maximize the benefits of agglomeration while minimizing environmental degradation and other potential adverse impacts of a growing number of city dwellers, especially in low-income and lower-middle-income countries where the most rapid urbanization is expected between now and 2050 (UN, 2018). Unplanned or inadequately managed urban expansion, in combination with unsustainable production and consumption patterns and a lack of capacity of public institutions to manage urbanization, can impair sustainability due to urban sprawl, pollution and environmental degradation. In recognition of their economic, social and environmental interdependence, the linkages that cities and small towns establish with surrounding rural areas should be strengthened. Governments ought to facilitate Sustainable Development in both urban and rural areas by delivering services and infrastructure improvements (SDG 9). Urbanization has generally been a positive force for economic growth, poverty reduction and human development. Cities are places where entrepreneurship and technological innovation can thrive, thanks to a diverse and well-educated labour force and a high concentration of businesses. Urban areas also serve as hubs for development, where the proximity of commerce, government and transportation provide the infrastructure necessary for sharing knowledge and information. Urban dwellers are often younger, more literate and more highly educated, are more likely to have access to decent work, adequate housing and social services, and can enjoy enhanced opportunities for cultural and political participation as well as gender equality (Cohen, 2006). Economies of scale in urban areas and technological innovation can facilitate the sustainable provision of infrastructure such as roads, piped water and electricity, as well as basic services such as education and health care, all of which are essential to achieve the Sustainable Development Goals. Government policies for planning and managing sustainable urban growth can help ensure that the benefits of urbanization are shared equitably. Policies that aim to restrict rural-to-urban migration are generally ineffective at forestalling city growth and can even result in economic, social and environmental harm. Sustainable urbanization requires that cities generate adequate income and decent employment opportunities; provide the necessary infrastructure for water and sanitation (SDG 6, SDG 3), energy (SDG 7), transportation and communication (SDG9) ensure equitable access to housing and services; minimize the number of people living in slums; and preserve a healthy environment within the city and surrounding areas. To ensure that the benefits of urbanization are shared and that no one is left behind, policies to manage the urban growth need to consider the needs of women (SDG 5), including for equal access to services, property rights and political participation; youth, including policies to provide education and employment (SDG 4, SDG 8) and focus on the urban poor and other vulnerable groups, including indigenous people. Assessing current and future needs with respect to urban growth and for setting policy priorities to promote inclusive and equitable urban and rural development should be based on up to date and coherent population estimates and projections. In order to systematically track levels and trends in urbanization around the world, contributing to the evidence base on urbanization, the Population Division of the

Department of Economic and Social Affairs of the United Nations has issued for several decades revised and updated estimates and projections of the urban and rural populations of all countries in the world and of their major urban settlements. Addressing inequalities is key to achieving Sustainable Development (Gaigbe-Togbe, 2015). Urban slum dwellers face greater exposure to environmental hazards, such as pollution, and suffer increased health risks as a result. Over the last 15 years, countries have steadily improved urban slums, characterized by housing that is non-durable or overcrowded, or that lacks access to improved water and sanitation or security against eviction, by managing to move millions of people out of substandard conditions and providing them with adequate housing. The majority of global people living in slums are located in three regions: Eastern and South-Eastern Asia (332 million), Central and Southern Asia (197 million) and sub-Saharan Africa (189 million) (United Nations, 2018b). Evidence from 191 Demographic and Health Surveys, conducted in countries of Africa, Asia and Latin America undertaken over the last several years, shows that infants and children residing in slums have substantially greater incidence of diarrhoeal illness than their urban peers and are less likely to survive to their fifth birthdays (Fink, Gunther and Hill, 2014). The urban poor in developed countries also face marked disparities in health and well-being.

1.3 SDG 4 and Education for Sustainability

So, what does it mean to be a global citizen today, and how do educators help students make sense of this topic? Recently, youth have shown some examples of their attitudes towards citizenship awareness. In fact, young people brought to the attention of policy makers global issues such as the climate emergency and racial injustice. The Global Climate Strike of 2019 saw at least 6 million people (Taylor et al., 2019) take to the streets when students and workers walked out in a coordinated demonstration that reached 125 countries (Milman, 2019). Eight months later, tens of thousands of protesters rallied against racial inequality after the police killing of George Floyd, an unarmed Black man in Minneapolis (Cave, 2020), giving global prominence to the Black Lives Matter movement. These are clear examples of how young people are at the forefront of a global reckoning, realizing they must inherit and confront centuries of social and environmental injustices that are strictly interlinked. Therefore, young people are the core of social transformation towards sustainability and education of young people is the basis of this challenge.

The Agenda 2030 SDGs offer one possible framework for analyzing the intersectionality among urgent global issues and for providing a common language for educators to critically engage with the Goals. In addition, they give a clear purpose to global citizenship education—or education in general (Leite, 2021). Education is at the root of one particular SDG: SDG4, which aims to ensure education for all, starting from basic education (Fig. 1.10).

Fig. 1.10. SDG4 targets.
(UN, 2015)

The first six of the SDG4 targets primarily focus on improvement of access and quality of education. The SDG 4.7 stresses the need to approach education for Sustainable Development and sustainable lifestyles: "help people develop knowledge, skills, values and behaviours needed for sustainable development". Specific objectives include providing more opportunities for technical training to youth so they can get better jobs; ending inequality in educational opportunities between men and women; providing the right education for children with disabilities, indigenous people and victims of conflict; improving school facilities to provide a safe and positive environment for everyone; increasing the number of trained and qualified teachers and promoting education for Sustainable Development (UNESCO, 2013). It can also enable individuals to better cope with and reduce their vulnerability to the dangers associated with climate change. Even if the subject of education for sustainability is explained in SDG4, a critical analysis of the Agenda 2030 as a whole raises that in each set of targets, at least one involves learning, training, educating or at least raising awareness of core Sustainable Development issues. Education has long been recognized as a critical factor in addressing environmental and sustainability issues and ensuring human well-being. Education can accelerate progress towards the achievement of all of the SDGs and therefore should be part of the strategies to achieve each of them (UNESCO, 2015, 2106). The role of education is a cross-cutting means of advancing the Agenda 2030, because it is associated with increased environmental and social awareness and action. Increased educational attainment helps build future people's lifestyles by reducing poverty, improving healthcare, advancing technology and increasing social cohesion (UNESCO, 2013).

Moreover, in 2017 the UN General Assembly also adopted a Global Indicator Framework (UN, 2017), presented as a dynamic review mechanism used to guide and monitor the implementation of each Goal (UN, 2020 b). This Global Indicator Framework also includes a call for increased education in three key areas: global citizenship, Sustainable Development, and climate change. The three key areas are spread across three SDGs: Quality Education (Goal 4), Responsible Consumption and Production (Goal 12), and Climate Action (Goal 13). This separation has some utility in terms of developing learning objectives and assessments. However, education should intersect all the SDGs in a holistic manner. According to the UN Global Indicator Framework, the achievement of the SDGs will thus in part be measured by the extent to which countries incorporate education on the three key areas into national curricula by 2030. Such indicators in relation with the corresponding SDG and target are reported in Tab. 1.1. In order to help accomplish the SDGs within the given timeframe, educators need definitions of the three key areas of education to improve. In 2019 at the Sixth Meeting of the Technical Cooperation Group (TCG) these definitions were proposed (UNESCO, 2019). (Tab.1.2).

Referring to Tab. 1.2, the ‘learning to live together’ and ‘learning to live sustainably’ represents a call for teachers and educators to engage pupils in an active role for sustainable lifestyles and building inclusive, responsible, climate-change resilient and peaceful societies. But the report entitled Education for Sustainable Development Goals (UNESCO, 2017) admits that “...not all kinds of education support

Sustainable Development". It is a call for pursuing new forms of education: " Education for Sustainable development (ESD) is holistic and transformational education that addresses learning content and outcomes, pedagogy and learning environments. Thus, the ESD does not only integrate contents such as climate change, poverty and sustainable consumption into the curriculum but also creates interactive, learner-centered teaching and innovative learning settings. What ESD requires is a shift from teaching to learning…the complexity of the world situation requires creative and self-organized action overcoming basic problem-solving processes that go strictly according to plan... People must learn to understand the complex world in which they live...".

GOAL	TARGET	INDICATORS
4: Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all	4.7: By 2030, ensure that all learners acquire the knowledge and skills needed to promote sustainable development, including, among others, through education for sustainable development and sustainable lifestyles, human rights, gender equality, promotion of a culture of peace and non- violence, global citizenship and appreciation of cultural diversity and of culture's contribution to sustainable development	4.7.1: The extent to which (i) global citizenship education and (ii) education for sustainable development, including gender equality and human rights, are mainstreamed at all levels in (a) national education policies; (b) curricula; (c) teacher education; and (d) student assessment
12: Ensure sustainable consumption and production patterns	12.8: By 2030, ensure that people everywhere have the relevant information and awareness for sustainable development and lifestyles in harmony with nature	12.8.1: The extent to which (i) global citizenship education and (ii) education for sustainable development (including climate change 3 education) are mainstreamed in (a) national education policies; (b) curricula; (c) teacher education and (d) student assessment
13: Take urgent action to combat climate change and its impacts	13.3: Improve education, awareness raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning	13.3.1: Number of countries that have integrated mitigation, adaptation, impact reduction and early warning into primary, secondary and tertiary curricula

Tab.1.1 *Global indicator framework for the Sustainable Development Goals and targets of the 2030 Agenda for Sustainable Development (UN,* 2020 b) (https://unstats.un.org/sdgs/indicators/indicators-list/)

Term	**Definition**
Global Citizenship Education (GCED)	Education which empowers learners of all ages to assume active roles, both locally and globally, in building more peaceful, tolerant, inclusive and secure societies. It can be summarised as ‘learning to live together’. It is based on the three domains of learning – cognitive, socio-emotional and behavioural. ● Cognitive: knowledge and thinking skills necessary to better understand the world and its complexities. ● Socio-emotional: values, attitudes and social skills that enable learners to develop emotionally, psychosocially, and physically and to enable them to live together with others respectfully and peacefully. ● Behavioural: conduct, performance, practical application and engagement. It includes cultural diversity and intolerance, gender equality and human rights and peace and non-violence
Education for Sustainable Development (ESD)	Education that empowers learners to take informed decisions and responsible actions for environmental integrity, economic viability and a just society for present and future generations. It can be summarised as ‘learning to live sustainably’. It covers sustainable lifestyles and ways of life, climate change, biodiversity, environmental sustainability, the greening of the economy and sustainable consumption, caring for the planet and disaster risk reduction.
Climate Change Education (CCE)	Education to help people, in particular youth, understand, address, mitigate, and adapt to the impacts of climate change. It encourages changes in attitudes and behaviours needed to put the world on a more sustainable development path and build a new generation of climate change-aware citizens. It covers various responses to climate change including mitigation, adaptation, impact reduction and early warning.

Tab.1.2. Key-areas of education in Education for Sustainable Development (UNESCO, 2019)

Addressing students to the Agenda 2030 Goals opens a pathway for shifting education systems away from their focus on workforce preparation towards the health and sustainability of our people and planet. This shift requires a re-examination of the fundamental values dominating formal schooling via a transformative learning theory. As Sterling argues: “education needs a significant degree of transformation itself, it is to be transformative in effect, rather than conformative” (Sterling, 2016). Organizing curricula around the global issues identified in the SDGs is a starting point for transitioning our schools to help solve the greatest problems facing humanity. Studying global citizenship only as a distinct subject or exploring climate change solely in science lessons inevitably confine these issues to niches, failing to present them as interrelated and interdependent (MGIEP, 2017). Instead of only associating those issues with single subjects, the SDGs as a whole may be used to support an integrated curriculum that combines environmental, social, and economic topics, encouraging a truly interdisciplinary perspective—notwithstanding their limitations (Sterling, 2016). The SDGs become a dynamic pedagogical tool that can be used to address the three key areas of education (global citizenship, sustainable development, climate change).

1.3.1 From environmental education to Education for Sustainable Development (ESD)

Despite the concept of 'sustainability' first emerging in the early 1980s, it was not until 1987 that this term began to form part of the vocabulary of environmental education. In “The World Conservation Strategy” (IUCN/UNEP/WWF, 1980) education is already seen as playing a key role in remeding global environmental and social concerns. It was the World Conservation Strategy which first redirected the goals of environmental education towards what it will be called “Education for Sustainable Development " (ESD). The 1980s were important years for environmental education also because in that decade an environmental education's holistic philosophy began to take root (Tillbury, 1995). This was reflected in the broadening nature and scope of environmental education, marked by moves towards an interdisciplinary dimension and from a more local to a global approach (Tilbury, 1993). The history of environmental education reveals that there is a connection between the changing concerns about the environment and the way in which environmental education was promoted.

It is in the Brundtland Report (WECD, 1987) that the key role of education in Sustainable Development first raised: “*But first and foremost our message is directed* *towards people, whose well being is the ultimate goal of all environment and development policies. In particular, the Commission is addressing the young. The world's teachers will have a crucial role to play in bringing this report to them. If we do not succeed in putting our message of urgency through to today's parents and decision makers, we risk undermining our children's fundamental right to a healthy, life-enhancing environment*". According to these words, teachers have the role to promote in pupils a culture of active players for social and environmental challenges. Then in the 1990s mounting concern over environment and development problems shifted its focus to environmental education for sustainability (Tillbury, 1995). The new decade prompted environmental education to take a more clear identity linked with problems of contemporary society. The result was an educational approach which not only considers immediate environmental improvement as the unique urgent goal, but which also addresses educating for sustainability in the long term. This new form of environmental education requires reconciliation between environmental conservation, human rights preservation and economic development. In 1991, the World Conservation Strategy—Caring for the Earth: a strategy for sustainable living (IUCN/UNEP/WWF, 1991) was launched. This document, like the previous World Conservation Strategy, also highlighted the key role of education in promoting sustainable lifestyles. Education enables pupils to become aware citizens who understand, appreciate and implement sustainable practices. Similarly, Agenda 21 of the Rio Earth Summit UN, 1992), called for the re-orientation of environmental education towards sustainability (ESD). Chapter 36 of Agenda 21 (UNCED, 1992) restated the importance of ESD and the need for considering all social, economic and political aspects of Sustainable Development. There was a change in focus from environmental education to ESD. Besides the protection of the natural environment, ESD also includes the interrelations between the social and economic spheres that can only be achieved through a broad understanding of the three dimensions: economic, ecological and social aspects of society and nature. The Thessaloniki Conference on Environmental Education (1997) put forward a declaration for adoption by all governments. This declaration states that progress on ESD is still not fully explored and that much work remains to be done. The declaration points out the need for integrating and coordinating efforts of governments, NGOs, local communities, financial organisations and other groups, in a number of key areas, including the change of behaviour and lifestyle, consumption patterns and the way that the natural environment is seen and dealt with. This declaration stresses that to achieve sustainability one needs to increase people's awareness about aspects like poverty, economic development, democracy and peace. It calls for a reorientation of the formal and non-formal education as a whole towards sustainability. Also, it points out that the current status of affair still lags far behind the objectives and goals set by Chapter 36 of Agenda 21.

As Gayford (1991) outlines, environmental education in general adds relevance to the school curriculum and is highly relevant to both the present and future needs of pupils and all of society. Contemporary environmental education is an approach to education that seeks to interest and involve students in major contemporary issues and in the potential impact of environmental issues on the future. In order to contribute in particular to the Education for Sustainable Development, students should increase their understanding of themselves and the world around them. It must encourage pupils to explore links between their personal lives and wider environmental and development concerns, by dealing with issues like consumerism and how the practices of business and industry influence their lives (Tillbury, 1995). In doing so, ESD prepares students for contemporary reality and action in their own territory. Fishbein and Cappella (2006) suggest that even attitudinal change is 'necessary but insufficient' to bring about a change in behaviour. They show that a person's behaviour is influenced by environmental factors and by their skills and abilities, as well as their intentions—and that intentions are formed by societal norms and perceived self-efficacy rather than just by attitudes.

Therefore, how can education play an effective role in promoting Sustainable Development (SD)? Different theories have been used, implicitly or explicitly, in answering this question. We can group them into three models:
1. education *about* Sustainable Development (model 1);
2. education *for* Sustainable Development (model 2);
3. critical education *towards* Sustainable Development (model 3).

Scott and Gough (2003) outline three theories linking learning, Sustainable Development and change, which correspond to these three categories. Education *about* SD dominates approaches to sustainability in most schools, providing awareness through knowledge, which should generate changes in attitude and then in behaviour. But albeit many education institutions have incorporated 'green' preambles, this was not sufficient to allow principles of Sustainable Development to leave deep imprints on education.

Education *for* SD is about practical and contextualised learning, about how to live a better life and care for the present and future of the earth. It focuses on actions which change attitudes and build lifelong awareness and thus lifelong practice.

Education *towards* SD is about what is to be sustained and for whom. We can answer that the environment is to be sustained for the purpose of human wellbeing, which leads to a focus on community-level participation and implementation. It emphasises generating knowledge through critical action and developing active and critical citizenship. Therefore ESD reflects mostly model 2, but also integrates principles of model 3.

Environmental protection in Sustainable Development discourse is linked with all other pressing human issues such as equality, fair distribution of natural resources, and human rights. Social and environmental interdependency is often framed within the context of human needs, deconstructing 'nature' or 'wilderness' in terms of 'natural resources' rather than finding a true balance between human and non-human needs (Kopnina, 2012). However, the risk is that environmental concerns could maintain an instrumental and anthropocentric worldview (Kopnina and Keune 2010) that does not necessarily exclude the interests of non-human species, but non-human-oriented interests are likely to be marginalized (Dunlap and Catton 1979). On the other hand, the ecocentric perspective poses humans within the 'nature' domain and are seen as part of the bio- or eco-sphere, but is not necessarily exclusive of social concerns and value to humans (Kortenkamp & Moore 2001). As human and environmental domains are intimately intertwined as acknowledged by most environmental ethics thinkers, ESD emphasizes environmental concerns in relation both to human and environment itself welfare. In the context of Sustainable Development and Education for Sustainability, the 'fight against pollution and resource depletion could go beyond only the central objective of the health, well-being and satisfaction of human wants and needs. The challenge is to overcome an anthropocentric view of environmental protection in an ecocentric perspective, that favours interests of non-human species independent of their value to humans, overcoming the dominant post-industrial neo-liberal anthropocentric discourse. The aim is a re-examination of an anthropocentric dominant western worldview in which humans are seen as superior to nature and able to solve all environmental problems (Dunlap & Catton, 1979). Following more 'deep green' perspectives, the environmental crisis calls for revision of major political, economic and social systems (Devall, 1993). An ecocentric perspective endorses 'biospheric egalitarianism', the view that all living things are alike in having intrinsic value, independent of their utilitarian usefulness to humans, thus embedding environmental ethics debate in the sphere of political theories of justice (Naess, 1973).

1.3. 2 Geosciences education as a key component of Education for Sustainability

Earth Science is the scientific discipline that explores our planet Earth and provides this knowledge and understanding. Recent surveys (Greco & Almberg, 2018; King, 2013) have indicated that Earth sciences education in schools worldwide has retained the same low profile that was noted in the previous century (King, Orion, & Thompson, 1995; Orion, Adams, King, & Krockover, 1999). Earth science concepts are often wrongly considered of less rigor and substance than other areas of science (Hoffman & Barstow, 2007), and educational methodologies often neglect the inquiry-based approach and the outdoor learning environment, often leading teachers to merely “teach to the test”. But there is growing evidence that citizens, young and old, need to be more informed and active in solving global problems, such as the current climate change, the need to exploit new minerals, make sustainable use of water resources and to protect bio- and geodiversity. Citizens cannot understand humankind’s rapid impact on Earth’s environments without first understanding Earth’s processes (Martin, 2018). For this aim, over the past four decades, Earth Sciences Education (ESE) research has been following the conceptual change, from a view of geoscience as a series of independent fields, towards its perception as a single, comprehensive system. Some of these thinking skills, like the understanding of deep time, cyclic thinking and system thinking, are quite unique to ESE, while others, such as logic and scientific thinking, are more general. Research has also suggested how to integrate the indoor learning environments (classroom, lab, computer) with the outdoor learning environments under the umbrella of the holistic Earth systems approach. It involves almost every critical component of our life on Earth, starting from the air we breathe, the water we drink, the food we eat, the energy we use, the buildings we live and work in, and the materials used for our daily lives.

Twenty-first century science tends to adopt an interdisciplinary perspective and a systems approach toward dealing with a broad spectrum of scientific domains. The influence of this tendency is well shown in the Geosciences, where the different fields are becoming increasingly enmeshed, forming a relatively new but dominant field known as Earth System Science (ESS). ESS works towards an integral and more holistic view of Earth, recognizing Earth processes as part of a system (Orion, 2007). This system is composed of five interrelated subsystems (geosphere, hydrosphere, atmosphere, cryosphere and biosphere) that are constantly recycling matter and energy from one subsystem to another. ESS studies involve understanding these individual systems, as well as how the systems interact with and influence one another. This includes recognizing that Earth systems are continuously changing, that systems must be understood over both time and space, and that processes that influence Earth systems do so across many scales, from micro to planetary, and over timescales ranging from milliseconds to millennia. Thus, the ESE approach creates numerous opportunities for social interaction and depends on students' social ability to interact with their peers in a learning process, and on the ability of teachers to deal with this social aspect. For example, teachers must be able to adjust the space of the laboratory to enable students' mobility between different groups, to facilitate students' interactions and to encourage spontaneous social interactions. The Earth systems approach is based on the construction of knowledge by learners through the mediation of the teacher, and is therefore based on a close engagement of the learner in the learning process.

Researchers have also suggested shifting the focus of the environmental movement towards developing environmental insight (Orion, 2007, 2017; Orion & Fortner, 2003) (Fig. 1.11).

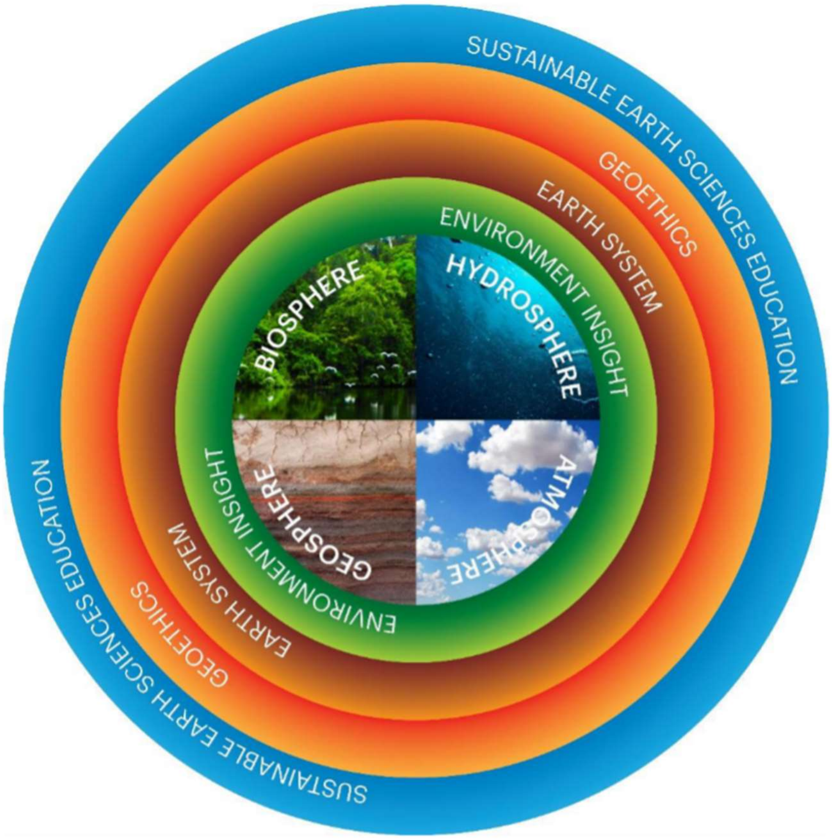

Fig. 1.11. Environmental insight view.
(Vasconcelos, 2021)

Environmental insight is composed of two central components: (1) the understanding that we live in a cycling world that is built upon a series of subsystems (geosphere, hydrosphere, biosphere, and atmosphere) that interact through an exchange of energy and materials; and (2) the understanding that people are a part of nature, and thus must act in harmony with its 'laws' of cycling. The study of the interacting Earth systems - within the dimension of deep time and the large spatial scale of geological processes – will enable students to appreciate the realistic influence of humans on the Earth in deep time perception. In addition, it will move away from the traditional altruistic environmental awareness approach towards the environmental insight (egocentric and geocentric) approach.

Geoscience focuses on complex issues such as the mutual influence among natural systems, the influence of human intervention on the earth systems, the use of the physical environment to produce energy, the sustainable development of natural resources and global changes in climate. In doing so, Earth sciences play a central role in facilitating the “Earth system governance”: the process of defining and developing socio-economic systems that will prevent drastic Earth system disruptions (Biermann, 2010). While consumption, inequality and population have increased extremely quickly, processes such as the extraction of resources from the system and the return of waste and pollution, climate change and the unregulated mining of raw materials are also simultaneously altering land cover, fragmenting ecosystems and reducing bio and geodiversity (Vasconcelos, 2016). Consequently, in the next future humanity may find that its environment is no longer fit to live in. To instill sustainability in our daily routines, we must go beyond the commons actions, changing them in a sustainable manner, answering to the imperative call for action. With globalization at the core of the contemporary economic and social dynamics, knowledge and education stand as progressively powerful determinants of dissemination of environmental issues. Although environmentalism is a well-known social movement that promotes social change behaviours on multiple scales (green technology, energy conservation, community gardening…) a gap between pro-environmental attitudes and practical behaviour has proven difficult to bridge.

Orion and Libarkin (2014) stress the potential of Earth science to better address the challenge of changing really environmental behavior. Helping students recognize how processes that operate on planet Earth interact to generate physical and biological diversity over vast and temporal scales is a unique feature of Geoscience. The dynamic balance of the Earth’s subsystems defines how our planet deals with unexpected agents that cause natural disruptions of the balance between them (Vasconcelos, 2021). Understanding how this dynamic works is of capital relevance to address Earth’s Sustainability with the aim to direct our behaviour towards the SDGs guidelines. Therefore, Geosciences become the major areas that can be used by teachers in conceptualizing sustainability (Hale, 2017).

Furthermore, Geosciences allow pupils to understand Earth as a system and sustainability issues improving system thinking. System thinking is an educational approach based on a holistic approach by accounting for the dynamic interdependencies among parts in a whole, so as to see a whole as a sum of its parts. This competency of thinking among pupils plays an important role in geoscience education, so much that it is one of its foremost challenges (Soltis, 2019). The development of system thinking requires a deep study of the cyclic pattern of the transformation of matter and energy among the subsystems. According to Vasconcelos (2021), the ultimate goal of Geoscience education is the development of environmental insight that recognizes the interworking relationships between Earth subsystems and reflects on one's own role in system Earth so as to continually evaluate geo ethical behaviours to preserve life on Earth. Within the dimension of deep time and large spatial scale of geological processes, students could appreciate the realistic influence of humans on the Earth in deep time perception. Orion (2019) recognizes that this approach moves students' environmental awareness away from the traditional altruistic approach towards a more geocentric perception.

Geoscience education has the potential to make pupils understand that even though the balance among the Earth systems is fragile the Earth will survive, but the humans may not survive. In fact, the feedback mechanism of the Earth systems allows subsystems to return to balance each time, but the imbalance that humanity causes has put us at risk, not the Earth. The COVID-19 pandemic is an effective example to make students think about how environmental insight is critical to preserve life on Earth.

Several recent pandemics were accelerated by anthropogenic changes such as climate change, deforestation, livestock production, increased hunting and wildlife trade (Vyas,2020). Preserving ecosystems and their endemic biodiversity is important when it comes to disease control, keeping possible pathogens inside those communities (Di Marco, 2020). The lockdown imposed in most cities has led to changes in societal behavior which, in turn, has had consequences on all Earth subsystems: geosphere (reduction of coal and oil consumption); hydrosphere (improvement of water quality); atmosphere (reduction of gas emissions). However, environmental damages were caused by growing amounts of unrecyclable medical waste (gloves, masks…) contaminating rivers, oceans and landfills.

Although critical thinking and system thinking continue to be mentioned as cross-cutting key competencies for Sustainable Development (Assaraf, 2005), the meaningful contribution of the Earth system approach and the environmental insight competency is not yet being acknowledged widely (Levy, 2016). Unfortunately, there is a gap between the educational potential of Geoscience and its low profile in schools. Therefore, a deep change in teachers' view on Geoscience education is necessary. Teaching geoethics, along with the promotion of environmental insight, will enable a shift towards a healthier and more equitable society as well as a cleaner environment. Geoethics allows the development of the target values of social responsibility, concern for others and harmony with nature. This new ethics embraces life in harmony with the natural world on which humans depend for survival and well-being. Moreover, the new ethics promotes socially desirable values such as fighting against poverty and hunger and requires individuals to commit themselves to working with and for others in the interests of equality, equity and sustainability. Therefore, learning activities will lead to the development of such an ethics for the acquisition of a personal responsible lifestyle against issues like consumerism.

Many of the themes within the SDGs are pertinent to geological research and practice as well as geoscience education. Gills (2017) lists some of several ways by which Geoscience contributes to Sustainable Development:

- Access to clean water and safe sanitation (e.g., identifying groundwater resources; preventing contamination).
- Food security and agrogeology (e.g., using local rock and mineral materials to improve soil fertility).
- Disaster risk reduction (e.g., understanding the physical science underlying the generation of landslides, earthquakes and volcanic eruptions; assessing exposure through producing hazard maps; reducing vulnerability through geoeducation initiatives).
- Energy supply and management (e.g., identifying the potential of a geothermal energy supply; understanding hydrocarbon potential and safe extraction of resources).
- Improved infrastructure and access to basic services (e.g., geomorphological mapping for road construction; characterising rock masses prior to dam construction).
- Environmental and biodiversity management and conservation (e.g., geochemical monitoring of pollution migration through an ecosystem).

Therefore, geological research, monitoring, innovation, and dissemination can drive widespread improvements to wellbeing and quality of life. In fig. 1.12 a matrix to visualize the role of Geoscience in helping to achieve the SDGs is shown. Analyzing the figure, we can see that geologists can contribute to achieving most of the SDGs. Gills (2017) in fact stresses:

- In 12 of 17 of the goals (71%), one or more aspects from the 'Earth Materials, Processes and Management' group are shaded within the matrix.
- In 10 of 17 of the goals (59%), one or more aspects from the 'Skills and Practice' group are shaded within the matrix.
- In 17 of 17 of the goals (100%) one or more aspects from the 'Earth Materials, Processes and Management' group or 'Skills and Practice' group are shaded within the matrix. The type of contribution required differs from goal to goal, with some requiring an input unique to the geology community and others requiring a promotion

of values or changes in working practices across all sectors, including the Geosciences. For example, geology is a foundational ‘knowledge source’ when considering clean water and sanitation (Goal 6), requires knowledge about ‘hydrogeology and contaminant geology’: an understanding of groundwater resources is essential to the provision and sustainable management of clean water for all. When examining the detail of this goal, the role of hydrogeologists working across all sectors is even more apparent, working to ensure sustainable groundwater withdrawals, the protection of aquifers and improvements to water quality by reducing pollution. The achievement of SDG 3 about good health and well-being can occur through their understanding of agrogeology, hydrogeology and contaminant geology. In other examples, geology is one of many communities that could seek to actively promote the values that the goals seek to convey. In the final column of the matrix, a miscellaneous aspect of geology is represented. When considering gender equality (Goal 5), for example, the geological community must take responsibility for ensuring that all opportunities presented within geology-based academia, industry and public sectors are equally accessible to all. Goal 5 includes eliminating all forms of violence and discrimination against women and girls in public and private spheres, and the use of trafficked individuals that it is a challenge related to some aspects of agriculture and mining (Wheaton et al., 20

Group Definitions		
Earth Materials, Processes & Management	Understanding of '**Earth Materials, Processes & Management**' is important to one or more targets/means of implementation relating to the given SDG.	Colour
Skills & Practice	Sharing of and/or changes to geological '**Skills and Practice**' is important to one or more targets/means of implementation relating to the given SDG.	Grey

Sustainable Development Goals (SDGs)			Geological Sciences: Earth Materials, Processes & Management: Agrogeology	Climate Change	Energy	Engineering Geology	Geohazards	Geoheritage & Geotourism	Hydrogeology & Contaminant Geology	Minerals & Rock Materials	Skills & Practice: Education#	Capacity Building#	Miscellaneous
1	No Poverty	End poverty in all its forms everywhere.	■	■	■	■	■	■	■	■	■	■	
2	No Hunger	End hunger, achieve food security and improved nutrition, and promote sustainable agriculture.	■	■		■	■		■	■			
3	Good Health	Ensure healthy lives and promote well-being for all at all ages.	■						■				
4	Quality Education	Ensure inclusive and equitable quality education and promote life-long learning opportunities for all.									■		
5	Gender Equality	Achieve gender equality and empower all women and girls.											[a]
6	Clean Water & Sanitation	Ensure availability and sustainable management of water and sanitation for all.							■				
7	Clean Energy	Ensure access to affordable, reliable, sustainable, and modern energy for all.			■	■				■			
8	Good Jobs & Economic Growth	Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all.			■			■		■			
9	Innovation & Infrastructure	Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation.				■						■	[b]
10	Reduced Inequalities	Reduce inequality within and among countries.											[c]
11	Sustainable Cities & Communities	Make cities and human settlements inclusive, safe, resilient and sustainable.		■		■	■	■	■	■			
12	Responsible Consumption	Ensure sustainable consumption and production patterns.			■			■	■	■	■	■	[d]
13	Protect the Planet	Take urgent action to combat climate change and its impacts.		■		■	■		■		■		
14	Life Below Water	Conserve and sustainably use the oceans, seas and marine resources for sustainable development.		■					■				[e]
15	Life on Land	Protect, restore and promote sustainable use of terrestrial ecosystems...*	■						■				
16	Peace & Justice	Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels.											[f]
17	Partnerships for the Goals	Strengthen the means of implementation and revitalize the global partnership for sustainable development.										■	

Notes

SDGs from United Nations (2015a).

* (Abbreviated) Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss.

Education and Capacity Building are important to some degree within every goal.

Miscellaneous

[a] Promoting equality of opportunities to all (including access to geoscience education). Eliminating all forms of violence and discrimination against women and girls in public and private spheres.

[b] Supporting research and development.

[c] Promoting equality of opportunity, and ending discrimination.

[d] Shared responsibility to improve sustainable practice, particularly in the private sector.

[e] Increased international cooperation on marine protection and research.

[f] Transparency of payments and contracts, helping to fight corruption.

Fig.1.12. Intersection between Geological Sciences topics and SDGs.

(Gills, 2017)

1.4 Education for Sustainability and Citizenship Education in Italian School Curricula

In 2010 the Italian School National Department pointed out the importance of legality and environmental sensitivity issues as well as Education for Sustainable Development, with particular regard to the development of social and civic skills such as energy-saving behaviour; the protection and enhancement of the artistic, cultural and environmental heritage (“Ministero dell’Istruzione, dell’Università e della Ricerca: MIUR”, C.M. n. 86 del 27 ottobre 2010). In 2015 Italian School Department Guidelines about Education for Sustainability (MIUR; Ministero dell’Ambiente e della tutela del territorio e del mare, MATTM, 2015) stressed that "*education is the only answer to the new demand for skills expressed by economic and social changes and that it is necessary to develop in students curiosity for the world and critical thinking*". This document cites the 2012 UNECE document "*Learning for the future: Competences for Education for Sustainable Development*" which recognizes a set of skills necessary to address sustainability education, as "learning to learn, to do, to live and work together, to be" and defines three guidelines such as "holistic approach, imagine the future, bring about change."

The 2015 Italian School guidelines for education for sustainability stresses that contexts and territories ought to become an active part to the processes of knowledge building that is based on interdisciplinarity and holistic approaches. The common objective is to lay the foundation for a new pact between institutions and citizens, through generations, for the development and growth of the country towards a sustainable future. In particular, for the first cycle of education (primary and middle schools) the document stresses the key-role and aims of citizenship education: "*The first experiences of citizenship means to discover the other by oneself and to recognize the relevance of others and their needs...respectful of others, the environment and nature. Our school has the task of training Italian citizens in a European and world context, an even more fundamental issue in the perspective of environmental education. In fact, all the citizens of the world, each for his own part, contribute to the protection of the environment*”. Science learning objectives mentioned in this document are:

- observation and interpretation of natural environmental transformations (by the sun, atmospheric agents, water, etc.) and those by man (urbanisation, cultivation, industrialization, etc.);
- recognition of all living organisms' needs, in relation to their environments;
- interpretation of environmental transformations, including global ones, in particular those resulting from humans' action;
- awareness about humanity's impact on Earth, the limited nature of resources, as well as inequality in access to them;
- the adoption of ecologically sustainable personal behaviour and choices;
- respect for biodiversity in environmental systems.

All these learning objectives include a deep learning of environmental sustainability, but sustainability topics have to be addressed by all teachers' subjects in an interdisciplinary manner.

In the light of Citizenship Education importance, the Italian School National Department formalized in 2019 a law for the integration of Citizenship Education in all School Curricula (MIUR, D.M. N.35 22 June, 2019). According to this new law, Citizenship Education could be addressed both as a distinct subject and as a matter spread in various disciplines. In both ways, interdisciplinarity should be the core of this issue. In Allegato A of this law, the three key topics of Citizenship Education are defined:

1. Italian Constitution and Law;
2. The Agenda 2030 for Sustainable Development;
3. Digital Education.

This is the first time that Agenda 2030 for Sustainable Development linked with the Constitution and human rights issues become compulsory for Italian School Curricula.

2- THEORETICAL FRAMEWORK

In 2002 the UN proclaimed the Decade of Education for Sustainable Development, ESD, (2005-2014), promoting the key role of education for the acquisition of knowledge and the development of skills and attitudes necessary for achieving the future challenges of sustainability. Therefore, education should help develop students' ability to constantly assess the environment that surrounds them, operating and adapting to it through continuous and interpersonal processes of revision of their frames of reference.

Referring to the five pillars of Sustainable Development (Planet, Prosperity, Partnership, People, Peace), ESD also has to intersect these dimensions.

1. Planet: environmental education can increase green knowledge and sustainability practices continue outside of school. It can also enable individuals to better cope with and reduce their vulnerability to the dangers associated with climate change; education is associated with increased environmental awareness and taking action (UNESCO, 2016).
2. Prosperity: education can help increase agricultural productivity, providing skills for green innovation; education reduces working poverty; education needs to keep up with labour market needs.
3. Partnership: collaborative learning and teaching are the most effective.
4. People: education improves health and reduces fertility rates; education vehicules gender equality; education reduces crime in cities; education improves cities' prosperity and makes them green. Increased educational attainment helps build future people's lifestyles by reducing poverty, improving healthcare, advancing technology and increasing social cohesion (UNESCO, 2013).
5. Peace: education can encourage constructive political participation. Conflict is destroyed by education (UNESCO, 2016).

As UNESCO highlights (2017), sustainability citizens are people who can speak up, collaborate and act for positive change. In Tab. 2.1 the key-competencies for sustainability are described. Competencies describe the specific attributes individuals need for action and self organization in various complex contexts and situations. They include cognitive, affective volitional and motivational elements; hence they are an interplay of knowledge, capacities and skills. Key competencies represent cross-cutting competencies necessary for all learners and are transversal, multifunctional and context-independent. The sustainability key-competencies represent what sustainability citizens particularly need to deal with today's complex challenges. They enable individuals to relate the different SDGs to each other-to see the big picture of the Agenda 2030. For each SDG, UNESCO (2017) describes the specific learning objectives in cognitive, socio-emotional and behavioural domains. The cognitive domain comprises knowledge and thinking skills necessary to better understand the SDG; the socio-emotional domain includes social skills that enable learners to collaborate, negotiate and communicate in order to promote the SDG (self-reflection skills, motivations, attitude, values). The behavioural domain describes action competencies.

According to UNESCO learning objectives for SDG1 (No poverty) and SDG2 (Zero hunger), students have to address topics as causes of poverty and hunger, such as unequal distribution of natural resources, climate change, environmental degradation, unsustainable agriculture and food waste. Learners could be able to reflect critically on the interrelation of poverty, hunger, natural hazards, climate change and other economic, social and environmental shocks and stresses. Therefore, learners can evaluate and implement action personally and locally and change their production and consumption practices to combat poverty and hunger. These are the main aims of the activity “How much earth in my dishes”, described in Chapter 3. The activity “Daily ecological rucksack” has been realized in line with the learning objectives, suggested topics and examples of learning approaches and methods for SDG12 (Tab.2.2; Tab. 2.3).

Teachers are called to develop pupils’ skills, attitudes and capacities necessary to engage them in sustainability with “heads, hearts and hands” (Sipos, 2008). Literature tells us that educators who can implement new educational resources and strategies can lead to good practices in the field of sustainability and promote hope and action among their students, inspiring them to become social innovators (Scoullos, 2004). Therefore, active learning and gaming approaches are useful tools to address sustainability issues, in an interdisciplinary framework.

Key competencies for Sustainability
1.Systems thinking competency: the abilities to recognize and understand relationships; to analyse complex systems; to think of how systems are embedded within different domains and different scales; and to deal with uncertainty.
2. Anticipatory competency: the abilities to understand and evaluate multiple futures – possible, probable and desirable; to create one's own visions for the future; to apply the precautionary principle; to assess the consequences of actions; and to deal with risks and changes.
3. Normative competency: the abilities to understand and reflect on the norms and values that underlie one's actions; and to negotiate sustainability values, principles, goals, and targets, in a context of conflicts of interests and trade-offs, uncertain knowledge and contradictions.
4. Strategic competency: the abilities to collectively develop and implement innovative actions that further sustainability at the local level and further afield.
5. Collaboration competency: the abilities to learn from others; to understand and respect the needs, perspectives and actions of others (empathy); to understand, relate to and be sensitive to others (empathic leadership); to deal with conflicts in a group; and to facilitate collaborative and participatory problem solving.
6. Critical thinking competency: the ability to question norms, practices and opinions; to reflect on one's values, perceptions and actions; and to take a position in the sustainability discourse.
7. Self-awareness competency: the ability to reflect on one's own role in the local community and (global) society; to continually evaluate and further motivate one's actions; and to deal with one's feelings and desires.
8. Integrated problem-solving competency: the overarching ability to apply different problem-solving frameworks to complex sustainability problems and develop viable, inclusive and equitable solution options that promote sustainable development, integrating the above mentioned competences.

Tab.2.1. Key competencies for sustainability (UNESCO, 2016)

Cognitive learning objectives	1. The learner understands how individual lifestyle choices influence social, economic and environmental development. 2. The learner understands production and consumption patterns and value chains and the interrelatedness of production and consumption (supply and demand, toxics, CO2 emissions, waste generation, health, working conditions, poverty, etc.). 3. The learner knows the roles, rights and duties of different actors in production and consumption (media and advertising, enterprises, municipalities, legislation, consumers, etc.). 4. The learner knows about strategies and practices of sustainable production and consumption. 5. The learner understands dilemmas/trade-offs related to and system changes necessary for achieving sustainable consumption and production.
Socio-emotional learning objectives	1. The learner is able to communicate the need for sustainable practices in production and consumption. 2. The learner is able to encourage others to engage in sustainable practices in consumption and production. 3. The learner is able to differentiate between needs and wants and to reflect on their own individual consumer behaviour in light of the needs of the natural world, other people, cultures and countries, and future generations. 4. The learner is able to envision sustainable lifestyles. 5. The learner is able to feel responsible for the environmental and social impacts of their own individual behaviour as a producer or consumer.
Behavioural learning objectives	1. The learner is able to plan, implement and evaluate consumption-related activities using existing sustainability criteria. 2. The learner is able to evaluate, participate in and influence decision-making processes about acquisitions in the public sector. 3. The learner is able to promote sustainable production patterns. 4. The learner is able to take on critically on their role as an active stakeholder in the market. 5. The learner is able to challenge cultural and societal orientations in consumption and production.

Tab.2.2. Learning objectives for SDG 12 (UNESCO, 2017).

Suggested topics for SDG12
Production and consumption history, patterns and value chains, and management and use of natural resources (renewables and non-renewables)
Environmental and social impacts of production and consumption
Energy production and consumption (transport, commercial and residential energy use, renewable energies
Food production and consumption (agriculture, food processing, dietary choices and habits, waste generation, deforestation, overconsumption of food and hunger
Waste generation and management (prevention, reduction, recycling, reuse)
Sustainable lifestyles and diverse practices of sustainable production and consumption
Labelling systems and certificates for sustainable production and consumption
Green economy (cradle-to-cradle, circular economy, green growth, degrowth)
Examples of learning approaches and methods for SDG 12
Calculate and reflect on one’s individual ecological footprint
Analyse different products (e.g. cell phones, computers, clothes) using Life Cycle Analysis (LCA)
Develop and run a (youth) action project related to production and consumption (e.g. fashion, technology, etc.)

Tab.2.3. Suggested topics and examples of approaches for SDG12 (UNESCO, 2017).

2.1 Holistic approach and interdisciplinarity to teach Sustainability

The broad agenda of the SDGs by its nature requires the participation of multiple disciplines and sectors to be delivered, as an important area of focus for business leaders, governments, universities, non-government organisations (NGOs) and the media. Given the breadth and the interconnectedness of the Agenda 2030, the SDGs cannot be pursued in isolated disciplines, as stated by DeFries et al. (2012). The need for adopting an interdisciplinary approach for ESD has been raised by several authors (Dale & Newman, 2005; Eagan et al., 2002; Luppi, 2011; Summers et al., 2005) and by Unesco. Reorienting the existing education programmes to include more aspects related to sustainability and its three pillars (society, environment and economy) should be achieved in a holistic and interdisciplinary context, with teachers weaving sustainability issues into curriculum (Unesco, 2005). "No one discipline can claim education for sustainable development on its own, but all disciplines can contribute" (Unesco, 2005, p. 31). Only by following an interdisciplinary approach, ESD will be able to confront "problems that cross traditional disciplines, involve multiple stakeholders, and occur on multiple scales" (Dale & Newman, 2005), such as climate change, poverty and inequalities, acknowledging the interdependence between society and ecosystems.

Although knowledge is usually fragmented in disciplines, in educational environments, interdisciplinarity increases the ability to understand the complex challenges the world currently faces (Eagan, Cook, & Joeres, 2002). Integrating disciplines facilitates problem-solving as it promotes better understanding of each part that comprises a problem and fosters solutions which blend concepts from different disciplines (Annan-Diab, 2017). Interdisciplinarity enables "mutual development of the distinctive areas of expertise which different subjects may have to offer" (Summers, Childs, & Corney, 2005).

Therefore, Education for Sustainability needs a holistic approach since environmental and development problems are not solely caused by physical and biological factors, but also by social, economic, political, historical and cultural elements. It acknowledges that the investigation of any environmental issue must involve the study of the intersection and interaction of all these elements. It goes beyond perceiving the environment as just a complex of natural systems and instead recognises the totality of the surroundings and links between human lifestyles and the use of nature. Pupils ought to comprehend how both ecological and socio economic systems are not merely the sum of the parts that constitute them but also the result of their interaction. A holistic approach also includes an investigation of issues of different social, economic and environmental scales: local, regional, national and global, including an exploration of the links between them. Such a holistic curriculum approach, combines and develops scientific enquiry, social science thinking and practical skills together, contributing to the education of the 'whole person' (Meadows, 2009). 'Holism' becomes the guiding principle of Education for Sustainability. A value is the pupil's acquisition of responsible attitudes or convictions that can consistently reflect in their behaviour.

2.2. Montessori pedagogy

During the last three years of my teaching career, I have taught in a Montessori's experimental middle-school course. Moreover, I have carried out some didactic activities for my PhD research with Montessori's classes. Therefore, some aspects of Maria Montessori's pedagogy have influenced my didactic approaches, especially the vision of a cosmic education that perfectly fits with ESD.

Although Montessori's cosmic vision and her ideas of cosmic education had all started to take on a definite form in 1935, they are still very current today. Montessori's own grandeur has to do with her way of looking at the world and at the human being in a cosmic manner because it is all-inclusive: Montessori looks at the world, sees the world on a very grand scale, that is, at the level of the universe with all of its interrelationships (Grazzini, 2013). It is this vision of an indivisible unity made up of energy, of sky, of rocks, of water, of life, of humans as adults and humans as children, that lends a sense of the cosmic to Montessori's thinking. Inorganic matter and biosphere are interlinked and one influences the other. Therefore, cosmic education helps the children to acquire such a cosmic vision of the world, which gives a sense of meaning and purpose. Cosmic education gives the children the opportunity and the freedom to explore, study, and acquire knowledge of the universe in its globality and complexity. This learning approach needs holistic, multidisciplinary and interdisciplinary teaching. Maria Montessori gives to human-beings the aim to act in this cosmic world: the child's cosmic task is to construct the human being itself, construct a man who will build peace, a man who is adapted to the world in which he lives and acts. This vision is very close to the Agenda 2030 call for active citizenship.

Therefore, ESD calls for an interdisciplinary approach that overcomes barriers among different school subjects and existing disciplinary “boxes” (Filho, 2000). These concerns raise questions about the need for innovative educational approaches that facilitate real cross-disciplinary thinking. How then do we provide students with the conceptual tools to move across disciplines to recognise patterns and causal relationships between economic, environmental and equity issues? Warburton (2003) suggests these educational principles:

-provide a wide range of conceptual and material content;
-illustrate interconnections and interdependence;
-stress dynamic rather than fixed structures and processes.
-develop an ability to evaluate critically ideas;
-valuation of environmental asset;
-equity.

Such an awareness is best developed within an integrated, interdisciplinary framework and requires the student to engage in comparative and synthetic thinking at diverse levels. In this context, a well-developed capacity for deep learning is invaluable. Although it has general pedagogical significance, deep learning is particularly crucial in the case of sustainability education where holistic insight and an ability to organise and structure disparate types of information into a coherent whole is central to the whole exercise (Warbuton, 2003). Deep learning involves paying attention to underlying meaning and is associated with the use of analytic skills, cross referencing, imaginative reconstruction and independent thinking. A unifying framework allows meaningful dialogue across conventional disciplines. This can be done by identifying key concepts and considering interpretations and implications of each concept in the environmental, social and economic spheres. Similarly, a single real-world issue can be addressed from different perspectives, with hands-on examples.

2.3 Active learning and cooperative learning

Several authors (e.g., Sharma, 2016; Hedden, 2017) span *active learning* based on constructivism as a strategic approach to address sustainability, since it is a complex and multi-faced topic, requiring a steep learning curve. Since the mid1990s traditional passive, behavioral approaches to teaching and learning have succumbed to more constructivist based views that recognize learners as active participants in their learning experience (Salas & Cannon-Bowers, 2001). The active, constructivist theory is based on the view that learners are active processors of content, in control of their own learning (Winne & Hadwin, 1998) and are active agents assuming responsibility and management in their own learning process. According to Huitt (2003), the emphasis of the constructivist approach is that “an individual learner must actively build knowledge and skills (e.g., Bruner, 1990) and that information exists within these built constructs rather than in the external environment”. The learner has control and makes choices as to engagement and outcome; it is a learner- centered environment. Bonwell and Elison (1991) define active learning as “anything that involves students in doing things and thinking about the things they are doing”. According to Montessori (1970), using his hands, that marvelous human gift, the child explores his world, develops his mental powers, and constructs his very self and, ultimately, the adult human being. All adults, as Montessori says, are “the child of the child” that they once were, or in other words, “The child is father of the Man”.

Research has demonstrated that active learning promotes the development of self-regulation and self-facilitation skills (Ivancic & Hesketh, 2000) which are the main components of metacognition (Brown, 1987). Historically, metacognition has been described as “thinking about your own thinking” or “reflections on cognition” (Schoenfeld, 1987). Pintrich (2000) makes the point “if students do not realize they do not know some aspect of factual, conceptual, or procedural knowledge, it is unlikely they will make any effort to acquire or construct new knowledge”. Intellectual maturity is also important for reasoning (Kuhn, 1991), thinking (King & Kitchener, 1994), and understanding (Basseches, 1984). Kegan (1994) demonstrated that metacognition is essential for reflective thinking and evaluative decision-making.

Cannon-Bowers (1998) and Salas (2001) noted that “metacognition emphasizes self-of one’s cognitive functions, which assists learners in becoming active in their education instead of being passive recipients of instruction” . Since the primary components of metacognition require self-regulation, planning, and monitoring in order to develop these skills, learners need a learning environment that facilitates self-directed and active learning (Sweller, 1983; Novick, 1991). This type of learning is an inductive process, where learning is developed through exploration and experimentation that stimulates the development of metacognitive ability (Ford,1995) as contrasted with a more deductive method where learner exploration is constrained by a passive pedagogy (Keith, 2005). Further, active learning requires skills of adaptive transfer where learners can create new scenarios and solutions to demonstrate understanding and then evaluate effectiveness (Ivancic, 2000). The active learning framework is based on the premise that teachers are distillers and facilitators of information who scaffold learning based on the foundations that learners build outside of the classroom from the deployment of self-facilitated metacognitive aptitudes. Teachers develop learner self-regulation and self-facilitation by stating expectations that promote learner responsibility while integrating instructional strategies to foster activity-based learning. Further, research has shown that a learner's knowledge about his or her own thinking, metacognition, impacts learning outcomes, and manifests in learners' efforts towards learning (Hartman, 2001).

Since sustainability and sustainability education are complex, global and local, social and individual topics, constructivism is the instructional design theory of choice. Planting the seeds of sustainability through education means learning by doing not learning by osmosis (Hedden, 2017). Using constructivism to teach sustainability de facto requires a hands-on approach whereby students learn by experiencing and interacting. It is practicum-based education, experiential by its very nature. By actively engaging in sustainability issues, pupils gain a deeper understanding of their complexity. Teaching students to become environmentally emancipated means preparing them for the real-world challenges of sustainability at all levels (local, national, and international). It also prompts them to develop their critical thinking and problem solving skills in order to tackle current sustainability-related issues and, where necessary, challenge the status quo.

Educators' goal is therefore to train those who will define future lifestyles towards more eco-friendly attitudes. As future decision makers, problem solvers, and change agents, students will benefit from learning about sustainability through full immersion (Hedden, 2017). According to King (1993), "active learning simply means getting involved with the information presented—really thinking about it (analyzing, synthesizing, evaluating) rather than just passively receiving it and memorizing it". Student involvement and participation translates into solving real-world sustainability problems, thinking critically. Through an ongoing process of knowledge co-creation and modification, students think and rethink, and then grow with each successive iteration. Using an active learning constructivist approach, students learn how to learn and are encouraged to be lifelong learners. 'Learning to learn and loving to learn' could become a pedagogical motto for ESD. Active-based learning is based on the premise that teachers are distillers and facilitators of information, developing learner self-regulation and self-facilitation by stating expectations that promote learner responsibility while integrating instructional strategies to foster activity-based learning.

As UNESCO (2012) highlights, ESD is concerned with all levels and types of learning: learning to know, learning to be, learning to live together, learning to do and learning to transform oneself and society. Therefore, to be effective, the approach requires participatory teaching and learning methods to motivate and empower learners to take action for sustainable development, individually and socially, in their own daily routine and in their social life.

This perspective led education to promote the connection between school and sustainable development through *cooperative learning*. Cooperative learning has witnessed an evolution in recent years from being a teaching and learning methodology to becoming a wider and richer educational movement which respects cultural and educational diversity and aims for greater social justice and opportunity as well as a vision for life (Pavan & Santini, 2013). Working in groups to think about sustainability topics, is an expression of civic participation, which aims to build a democratic, equitable and sustainable future for the planet and its inhabitants. Cooperative learning embraces the values and practice of positive interdependence, distributing and sharing leadership and individual accountability, combined with group accountability, improving of social skills, creation of reflective practice. From this position cooperative learning becomes an ideal vehicle for reaching the social and cultural goals of ESD. As such, sustainability education and a thirst for learning go hand in hand. Since another purpose of ESD (UNECE, 2005) is that individuals reflect on the interdependence between the contexts of belonging (environment, labour, economy, relationships) and act towards a common vision, cooperative learning at school is a community of practice on a small scale. The co-operative work becomes effective if it is connected to real life. Therefore, pupils can evaluate real situations, solve problems in a creative manner, make decisions, think about the acquisition of knowledge, consider the limits of personal and collective responsibility and use social skills and competences in mediating potential conflicts.

Team working vehicle sustainability values as partnership and democracy from real experience. Dewey (1954) believed that “if children have to learn to live in a democracy, they must experience the process of democracy in classroom life - a process which includes substantive opportunities to make meaningful choices and build productive relationships based on genuine respect and empathy”. This approach encourages social competences as the acceptance and enhancement of any diversity; autonomy and identity as part of diverse groups; other competences that enable individual and social action to protect nature and environment; to share strategies and solutions towards more eco-friendly lifestyles; to develop social and individual wellbeing.

2.4 Game-based learning

Literature tells us widely that games represent excellent educational environments and serious ways to learn (Tilbury, 2008; Katsaliaki, 2015; Davis, 2006). Games can help to deepen the participant's understanding and help them to apprehend diverse facets of reality in new and more comprehensive ways. Through problem solving, collaboration, negotiation and peer-to-peer learning, games require cognitive investment, emotional commitment and active participation for engagement and deeper learning (Chapman and Dunkerley 2012). It is known that we learn more and better when we enjoy what we are doing and the key principle to motivate and engage players in learning processes is leveraging the intrinsic connection between fun and learning. In fact, in order to play the game, players must learn about elements of the game system such as goals and rules and develop individual and social skills. If players do not have anything new to learn, discover or improve they will not feel challenged and enjoyed. Learning can be considered an essential determinant of the game fun, engaging players at a cognitive and emotional level and this is what Education for Sustainability needs (Fabricatore, 2007).

Education for Sustainability, in particular, needs tools and educational approaches that foster system thinking, engaging players in cognitive demanding tasks, requiring problem-solving and decision-making skills (Fabricatore, 2012). In fact, games support knowledge and skills learning through fun, in a situated and meaningful context. Furthermore, as Fabricatore (2012) stresses, games present a high potential to address a complex issue as sustainability from multiple perspectives and require players to collectively engage in the pursuit of a common goal. For these reasons games allow students to engage in sustainability topics as a whole through a contextualisation integrating the social, environmental and economic dimensions. All players have an essential role in order to reach a common aim and this is a small-scale example of the global partnership necessary for achieving sustainability. Players receive just-in-time feedback, affording a situated and systemic understanding of the consequences of their actions. According to Deieman (2006) games, and especially games that deal with 'systems behavior,' are tools that we can use to apprehend and experiment behaviors that will transform unsustainable into sustainable societies. Additionally, there must be the element of emotional attachment to the subject of study.

The challenge of ESD goes much further than merely a quest for multidisciplinarity. It is multidisciplinary but, at the same time it is oriented towards effecting change, based on certain values and visions of a desired future state based upon those values. The word ‘empathy’ is a word that comes to mind when envisioning the consequences of this challenge.

When we not only seek to analyze but also wish to change, and when this change is based on certain values, the consequences are that certain levels of emotion and emotional attachment are essential. The contribution of games to ESD depends on their extraordinary potential to motivate players and emotionally engage them in the game dynamics. Emotional involvement and commitment is essential to engage in sustainability, the same way that motivation and fun are fundamental to engage players in the game. This means that we need to develop a certain emotional relationship with the subject we learn and teach; in this we are seeking to integrate apprehension with comprehension. In fact, according to Kolb’s (1984) experiential learning theory, learning is the result of comprehension and apprehension as well as transforming through intention and extension (Fig.2.1).

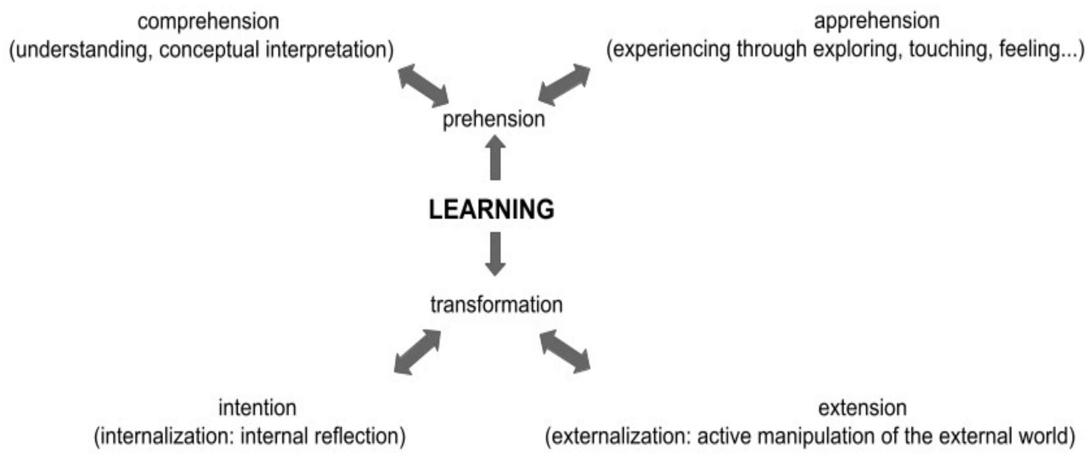

Fig. 2.1 Different forms of learning
(Kolb, 1984).

Dieleman stresses that sustainable development should focus on education that relies on apprehension and extension since the combination of those two processes leads towards diverting knowledge that facilitates understanding and motivates people to contribute to changing the systems from unsustainable to sustainable. But since ESD requires, at the same time, that the student develops a certain emotional relationship with the subject of study, education should also rely on apprehension and intention.

Finally, the usage of the appropriate tools and a sound multidisciplinary understanding of the subject of study are equally indispensable to help the student develop an emotional attachment and the capacity to transcend existing contexts and paradigms. This means that ESD should be based on a well balanced mix of apprehension and comprehension, as well as intention and extension. Games represent an effective tool for achieving these four types of learning, in the ESD. Playing games is an appropriate activity in the context of learning for sustainability and especially in the context of experiential learning. When students play games, they can simulate and create realities, with certain mutually accepted rules, roles, conditions and assumptions. When pupils play, one can easily 'take the role of others' and develop an emotional understanding (apprehension) of why others act as they do. The beauty of playing games is that students can 'learn by doing' and 'learn by failing' without negative consequences for the real world. They can simulate certain realities, play, manipulate and experiment and experience what the consequences are or what they might be. In case the consequences are negative, students learn what not to do and can design alternative approaches. The added value of games compared to experiments is the fact that within games, one can combine aspects of comprehension and apprehension, as well as processes of intention and extension. Since students will face work or internship's reality, they should be educated in finding tools to master the challenges they will meet in order to change the existing contexts. On the other hand, they have confidence with the real issues before starting to criticize. Playing games can help and provide students with an understanding of the subtle differences between mere un-constructive critique and attempts to change contexts.

In Tab. 2.4 a summary of the main functions of games are listed (Dieleman, 2006).

Board games, in particular, have been tested as effective learning tools (Gobet 2004, Shanklin 2007, Yoon 2014) thanks to some important characteristics:

1. The playful and immersive nature of board games facilitates attention, concentration and motivation of players;
2. In the course of the game the players experience a "suspension of disbelief" that prepares them to accept ideas even far from their everyday experience (Montola 2005);

3. Board games allow a “learn by doing” approach (Prensky 2007) providing an hands-on and heads-on skill and knowledge development;
4. Thanks to competitiveness and will to win players are urged to deeply understand the rules behind the game;
5. Downtimes, which are characteristic in board games (for example in the waiting of the opponent's moves), together with the playful and competitive atmosphere promote reflections and discussions among players;
6. These downtimes also promote the inclusion of clarifications and explanations in a natural and not disturbing way by teachers or scientific animators during the game course.

GAME’S FUNCTIONS	
Learning experiences	‘learn by doing’ without creating real consequences for the outside world
Shared experiences	foundation of shared problem definitions and shared views of solutions that can help the learners make further progress toward SD; playing games with people with dramatically different backgrounds, help to create, at least, one shared experience
Team-building	Playing games that facilitate communication and collaboration usually do result in better team performance and provide a sense of belonging to a team
Knowledge of oneself	By playing games, participants gain insight into their attitudes, values and thought processes; they can help the gaming participants discover the implicit assumptions that they have in life, but that may not necessarily be shared by others; playing systems games helps participants understand and feel the limitations and possibilities to change the system and this is essential for helping people envision the changes that need to be made and to empower them to make the changes in ‘real life’ that are essential for SD.
Test alternative solutions	Playing games allows simulating diverse realities, manipulating reality and experiencing the resulting consequences, within the safety of the simulation; while one player is testing alternative solutions one also learns much about one’s self while creating shared experiences for all participants; the system characteristics of SD make it difficult to predict the outcome of interventions, in the real world, but the simulations may help the participants to be more open to explore ways of moving forward
Fun and entertainment	Such ways of ‘learning,’ are very important because they generate positive mental energies and enthusiasm for participants to engage in the complex challenge of SD

Tab.2.4. Game-based learning functions (Dieleman, 2006).

Game features are able to generate adaptive responses by challenging individual and group behaviours if they are specific problem solving activities (Schell 2008). In addition, unexpected events introduced into a game during play may inspire students to understand and alter their behaviours (Miller and Page 2007). Such ‘mutual adaptations' may affect players' objectives and challenge thinking by encouraging behaviours to be re-evaluated in response to unexpected events. These unexpected events may require adaptive responses to cope with the added complexity introduced (Bloom 2010). Lizzio and Wilson (2008) consider such game-problems are valuable as they deliver opportunities to develop ideas, promote collaboration and change behaviours in the safe environment of the game. Ellison and Wu (2008) also highlight the value of game-problems and suggest they can drive learning for good practice as they are able to generate both an individual and collective sense of responsibility within players. If at the end of the game students are debriefed, it provides an opportunity to use a constructivist approach to learning that allows them to construct knowledge through reflection on game-play experience (Krause and Coates, 2008). This debriefing may help students to engage in a community of learning that enables them to share groups' game experiences. The opportunity to collaborate may present challenges to groups' and individual players' behaviours and encourage the development of alternative and/or combined operating strategies.

2.5. Distance learning during Covid-19 pandemic

Due to the COVID-19 pandemic, schools facing distance learning struggle with preserving human interactions among the school community. Didactic activities that have been realized using practical tools (sheets, pictures, board games) can be converted in a digital version by including them in a virtual world.

The use of virtual environments can partially overcome distance learning issues, allowing teachers to set up synchronous collaborative activities and group communication with a sense of presence (Occhioni & Beccaceci, 2021). The rising need of such virtual environments gives a good opportunity for development of different topics on various platforms. According to Girvan (2018) a virtual world is a "shared, simulated space" which is inhabited and shaped by its inhabitants who are represented as avatars. The avatars mediate our experience of this space as we move, interact with objects and interact with others, with whom we construct a shared understanding of the world at that time. Nowadays there is a growing interest in the use of virtual reality environments because "through immersive education participants can be offered a feeling of 'being there', through a synchronous connection that allows them to communicate with a sense of presence" (Contreras-Mendieta, 2018).

2.6. Aims of the study

An experimental study has been carried out in order to find new effective approaches to teaching Geosciences, focusing on topics related to Sustainability. The choice of research subjects arises from both the many connections between Sustainability topics and everyday lifestyles and from their interdisciplinarity. This interdisciplinarity is in line with the Italian School Citizenship education guidelines about Sustainable Development teaching and UNESCO key-competencies for Sustainability.

Sustainable consumption and lifestyles topics have been chosen in this PhD study because they are suitable for many laboratorial and practical didactic activities. Moreover, teachers can approach socio-economic issues both globally and locally with a contextualization in their own territory. The research on sustainability aspects and the realization of didactic materials for school experimentation have been set up taking inspiration from Geosciences topics related to everyday life. In more details, the Geosciences topics covered are georesources, water, carbon and ecological footprints, waste, sustainability and sustainable lifestyles.

The study has been proposed with the dual purpose of spreading Earth Sciences topics among k6-k8 students and of using such topics as interdisciplinar vectors in order to promote eco-friendly behaviours. Understanding how to improve pupils' ability to establish the relationships between humans and the environment and justify this relationship is essential to make the younger generation become conscious and responsible towards the environment itself.

Finally, the specific objectives of this research are:

-to improve students' interest and active participation in addressing Agenda 2030 and Sustainability topics, through engage questions, problematic situations, hands-on activities and gaming;

-to realize interdisciplinary didactic activities on Sustainable Development using experiential learning;

-to verify how pupils can identify and justify relationships between their everyday life actions and the environmental impacts of these actions (such as land and water consumption, CO_2 emissions, global warming, etc.);

- favourite crirìtical thinking about eco-friendly sustainable daily behaviours;

-use gaming and distance learning to ensure Sustainability topics dissemination during COVID-19 crisis;

- ensure social competencies and digital skills improvement in distance learning.

3- MATERIALS AND METHODS

As described in Chapter 2, the topics of this PhD project are Sustainable Development and lifestyles with a special focus on sustainable resources. In this frame, several didactic activities on Sustainability, directed to Italian students in the age range of 11-13 were realized and experimented at school and preliminary tested with a group of teachers (Fig. 3.1).

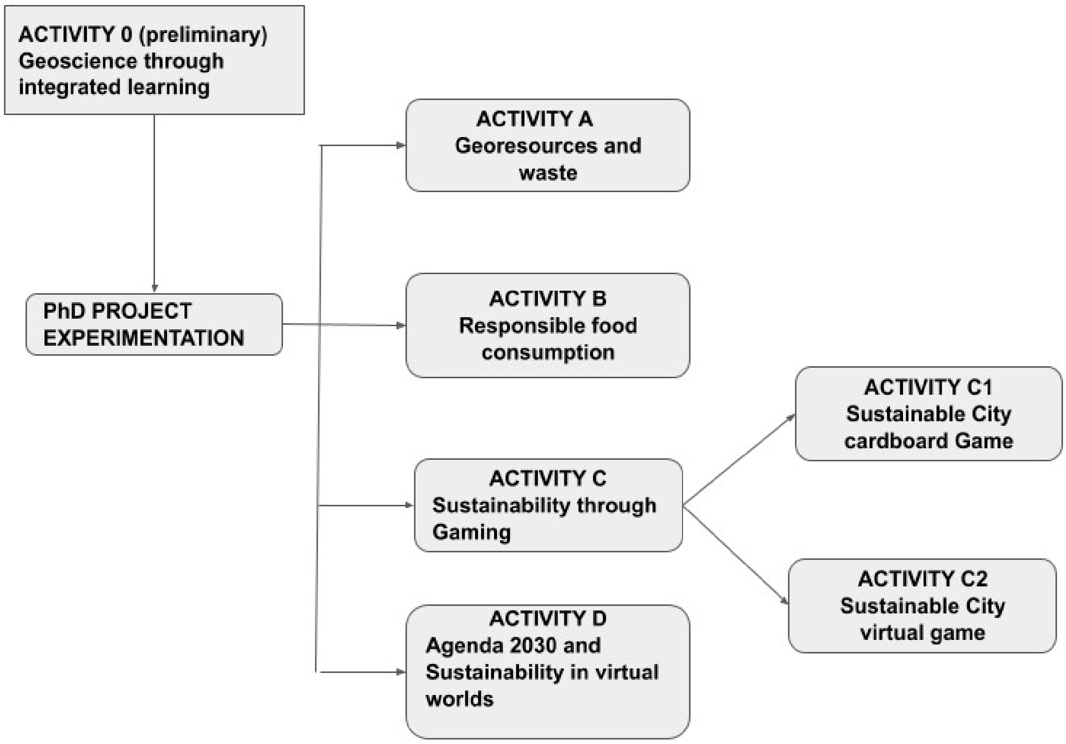

Fig. 3.1. Experimentation structure.

Figure 3.1 shows how the Research project was structured, from a preliminary activity to all the others, using a group of topics and integrating different disciplines and everyday activities to deal with the theme of Sustainability.

The description of this Research is reported in Tab.3.1.

TITLE ACTIVITY	TOPIC	MODE	TARGET	SCHOOL and LOCATION	TIMELINE	MATERIALS
Activity 0. A preliminary study: "*I will not crumble: the earthquake among science, poetry, technology and music*"	Seismic risk	experiential activity - in presence	k-8 students (27)	"IC via U.Bassi" -Civitanova Marche	6 hours	
Activity A. Georesources and waste *The Wasteberg activity* *The daily ecological rucksack*	The ecological footprint of everyday life actions	experiential activity- in presence	k-6 students (45)	"IC via U.Bassi"-Civitanova Marche	4 hours	Annex 1 Annex 2 Annex 3
Activity B. Responsible food consumption *How much Earth is on my plate?*	Responsible food consumption	experiential activity -in presence	k-7 students (45)		2 hours	Annex 4 Annex 5 Annex 6
Activity C1. *Sustainable City Game*- Cardboard Version	Agenda 2030 and SDGs Responsible lifestyles	Experiential activity - in presence	teachers (24) K6-K8 students (112)	V Summer School- Geology Division- Camerino "I.C.via U.Bassi"-Civitanova Marche I.C. "E. Paladini"-Treia I.C. "De Magistris"- Caldarola	2 hours	Annex 7 Annex 8 Annex 9 Annex 10 Annex 11
Activity C2. *Sustainable City Game* in Sustainability Hub- Virtual version	Agenda 2030 and SDGs Responsible lifestyles	Online activity (distance learning)	21 teachers k6-k10 students (86)	"I.C. E. Mestica"- Cingoli "I.C. "De Magistris"- Caldarola "I.C. Cremona 1-Campi "Cremona "I.C. Nettuno 1 Scuola De Franceschi "- Anzio I.T.I"Galileo Galilei"Gorizia	2 hours 2 hours	Annex 12 Annex 13 Annex 14
Activity D. *Sustainability Hub* planning	Agenda 2030, Georesources Ecological footprint, Global issues	Team-work with (M. Occhioni)			2 hours	

Tab. 3.1. Research project description.

In this chapter a brief introduction follows, referring to each activity, which will be explained in detail in the results section (Chapter 4).

Activity 0- Geoscience through integrated learning

"*I will not crumble: the earthquake among science, poetry, technology and music*" is a preliminary study to investigate the learning-by-doing approach to vehicle Geoscience topics (earthquakes and seismic risk) using interdisciplinarity.

Activity A -Georesources and waste

It deals with topics such as the responsible use of georesources, waste and the ecological footprint. Chapter 4 (paragraph 4.2.1) introduces a first activity on this topic, "The Wasteberg", about the georesources consumption and waste production linked to daily-use goods. Since this activity is well described in the PhD thesis of a colleague from my research group (Stacchiotti, 2019a), materials and methods will not be reported here in detail. However, results of the experimentation will be presented in the paper "*WASTEBERG: a didactic activity about waste and sustainable use of georesources in relation to the Agenda 2030*" in par.4.2.1, which was carried out in collaboration with other authors.

As a follow-up work, "*The daily ecological rucksack*" activity, deepens these topics focusing on the ecological footprint of everyday life actions. Materials and methods used for this activity will be explained in paragraph 3.1. It was tested on K-6 students attending "Istituto Comprensivo via Ugo Bassi" in Civitanova Marche.

Activity B- Responsible food consumption

"*How much Earth is on my plate*?" was investigated on the same pupils, one year later (K-7). The choice of following up the same pupils is in order to monitor the improvement in sustainable lifestyle awareness.

Activity C - Sustainability through Gaming

Activity C1 "*The Sustainable City Game - cardboard version"* was experimented first with a group of teachers, during the 4th Geoscience Summer School (2019) in Camerino, and with 112 students from some schools of the Marche Region. The experimentations of these activities have been carried out in presence and with the support of class teachers (Science and Geography). The teachers involved carefully observed the activity, monitoring the group and working in collaboration with the researcher. The project was approved by the class teachers' team as an integral part of the school curriculum.

Activity C2 *"Sustainable City Game" - virtual version activity* is the digital version of the Sustainable City-game, realized in a virtual world based on the 3D Opensimulator platform that can be accessed by teachers and students as avatars. The game resides on a virtual island, Sustainability Hub. This island is a part of the virtual world Techland, focused on Math and Science (Occhioni, 2017). The experimentation was carried out both with teachers and students.

Activity D Agenda 2030 and Sustainability in virtual worlds

The activity regards the planning of the *Sustainability Hub*, in collaboration with Michelina Occhioni, the colleague PhD student owner of the virtual world Techland. Sustainability Hub is an Opensimulator-based virtual island dedicated to sustainability topics and Agenda 2030 goals. Teachers and students can access the island as avatars and interact with objects and other avatars. This educational activity was experimented with K7-K8 students, who accessed the Sustainability Hub from their home during COVID-19 lockdown. After an initial training to master how to move and act in the world, teachers and students were free to explore the educational paths for 2 hours and were involved in various tasks. The Sustainability Hub is structured in a Welcome Area and five educational sections. These sections are respectively focused on actual global issues, georesources and circular economy, sustainability indicators, the Agenda 2030 goals, the Sustainable City Game. Students/avatars can reach each area both sequentially and randomly.

3.1. Materials and methods - details

Chapter 4 (Results) includes some full-text articles related to all these activities tested. In particular, these papers report the experimentation results, while briefly describing methods and materials. For completeness, these will be described in more detail in this chapter, in the following paragraphs.

3.1.1. Activity A (Georesources, waste and footprint) - *The daily ecological rucksack*

This is a practical activity realized using raw materials and ready-to-use tools (sheets of paper, boards, pictures, pieces of packaging, videos) about the ecological footprint of everyday life actions. The experimentation of the activity was carried out in two classes of 11-years-old-students, in the presence of Geography and Science teachers with the roles of observer and helper during the activity. The activity topic is the ecological footprint of everyday life actions, which is divided into two parts, two activities linked to each other. The first one is called "*My daily ecological rucksack*" and is divided into 2 lessons and 7 phases, as described in Tab.3.2. The second part is called "*Reduce your footprint*" and is a team challenge, as a conclusion of the experimentation.

Pupils worked in groups chosen on the basis of four members, since four are the number suitable for working in small groups. Moreover, if pupils have been adequately trained, working in small groups is perfect for cooperative learning. The groups' formation is crucial for learning success, so it was delegated to class teachers because of their familiarity with pupils and dynamics of the class. The teachers set up heterogeneous groups on the basis of two key informations: students' preference about their own co-workers and the need to get pupils with complementary skills and competences to work together (Bazarra et al., 2016).

Preliminary step: *Pre-activity questionnaire* to evaluate pupils' environmental and sustainability awareness				
Title	**Phases**	**Timeline**	**Didactical approaches**	**Description of the activity**
My daily Ecological Rucksack	1. Engage	10 min	Engaging video and brainstorming	The video makes pupils think about humans impact on the Earth planet and future perspectives about the relationship between people and our planet
	2. Introduction of Agenda 2030	50 min	Interactive lesson In depth video	The researcher showed pupils a PPT presentation, discussing topics such as water, carbon and ecological footprint, natural resources value, Sustainable Development and Agenda 2030 Goals. Malala's video has been a starting point for the following discussion.
	3. Daily waste-bag (homework)+ Group discussion (school)	10 min (home)+ 15 min (school)	Practical task about pupils daily lifestyle (at home) At school: team-work	Pupils collected at home, in a bag, several pieces of products' packaging and plastic bottles thrown away in one day. Moreover, students took notes on coloured papers about water consumed (blue paper) and organic waste produced (green paper) during the day. The following day, at school pupils were divided into groups, discussing the waste produced and the water consumed in one day because of simple everyday life actions.
	4. The favoured food waterwall	5 min	Learning by doing Cooperative learning	The working group chose a favourite food and represented its water footprint in the *Food waterwall*. This *waterwall* is a table with a lot of rows and columns, composed of boxes (to be coloured). Each box represents one litre of water.
	5. Smartphone ecological footprint	5 min	Learning by doing Cooperative learning	The working group calculated the ecological footprint of their mobiles (total)
	6. Daily ecological rucksack computation	60 min	Learning by doing Cooperative learning Brainstorming	Students calculated the water, carbon and soil footprint of their daily actions (washing, dressing, drinking water in plastic bottles, eating, using smartphones and computers…) with the help of reference data tables and operational sheets. At the end of activity, working groups discussed the data obtained. A brainstorming closed the lesson.
	7. Sustainability tree	following days (after experimentation)	Practical task about pupils daily lifestyle and responsible behaviours	In the following days, students collected pictures of simple sustainable actions they carried out at home. The "Sustainability tree" is a cardboard poster in the shape of a tree, where students could attach these photos.
Reduce your footprint		20 min	Learning-by-playing	Game-challenge. The teams had to join the pieces of a puzzle representing everyday life actions with the corresponding ecological footprint picture, from the biggest to the smallest one.
Final step: *Post-activity questionnaire* + *satisfaction questionnaire*				

Tab. 3.2 Description of the daily ecological rucksack activity.

At the beginning of the first lesson, as an engaging phase (phase 1), an emotionally involving video ("*The colour of your dream city*", https://www.youtube.com/watch?v=rASj9loN0rk) was shown. In this video a group of kids and their parents share their vision of the future of the world nowadays afflicted by serious environmental problems. Then, a brainstorming phase was carried out in order to discuss with students their vision of Earth's environmental condition and social problems, future perspectives and possible solutions. With the help of the history and geography teachers, social issues like global poverty and inequalities were discussed.

A brief introduction to the Sustainable Development, Agenda 2030 and ecological footprint topics followed (phase 2), using an interdisciplinary approach and a video about Malala Yousafzai making appeal to young people and presenting the Agenda 2030 (https://www.youtube.com/watch?v=T__s__oDGOQ&t=204s). Previously, the teacher of Italian had already approached students to the story of Malala, her fights against inequalities and her speeches to the UN Assembly. Therefore, students appreciated the video because of their familiarity with this character and Malala's young age.

The discussion about products' ecological footprint raised the pupils' previous knowledge about the production process of some materials, like paper, plastic, aluminium and glass they had studied with technology teachers. Then, the researcher gave students a task to carry out in preparation of the following meeting: the preparation of a personal "daily waste-bag". The "waste-bag" was a simple bag filled up with objects as symbols of daily consumption and waste production: pieces of products' packaging, plastic bottles and sheets of coloured paper (green for organic waste) and blue (for water consumed). In these sheets students had to write notes about food thrown away in the garbage and all the daily actions that required water consumption.

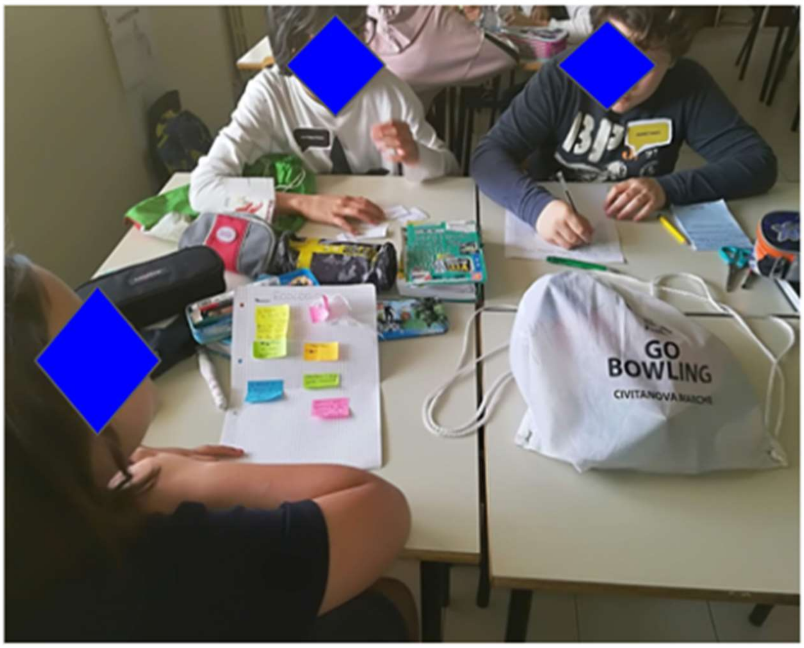

Fig.3.2. Pupils working in the daily ecological rucksack activity.

In the second lesson (phase 3), students were divided into groups of 3 components with specific tasks (the leader, the mathematician and the environmentalist). Each group discussed the daily "waste-bag" of both their natural resources consumption (e.g. water for drinking and washing) and waste production (packaging, food leftover, objects and products packaging thrown into the trash) (Fig. 3.2). In this phase, the idea of how many types of waste are produced in a day began to spread among pupils.

In order to introduce the concept of the ecological footprint of a product, each group calculated the water footprint of a favoured food (phase 4) and the water, carbon and ecological footprint of their smartphones (phase 5). In phases 4 and 5, the researcher gave students some reference data tables and operational sheets with some boxes to be coloured, on the basis of the footprint numerical values (with a specific measurement unit). The "waterwall", for example, is a table with a lot of rows and columns, composed of boxes, where each box represents one liter of water. In phase 6, groups calculated the water, carbon and soil footprint of their daily actions (washing, dressing, drinking water in plastic bottles, eating, using smartphones and computers…) with the help of reference data tables and the operational sheets prepared. In Fig. 3.3 an example of an operational sheet is represented. Tab.3.3 shows the didactic and educational objectives of the activity.

ATTIVITA' ZAINO ECOLOGICO

Nome…………………….. Classe……….. Data…….

AZIONE	CONSUMO DI ACQUA/ IMPRONTA IDRICA	CONSUMO DI SUOLO	IMPRONTA DI CARBONIO
Bere	a. Quanti l di acqua bevuti?…………….. b. Calcolo dell'impronta idrica delle bottiglie di plastica utilizzate:…………………………………………………	a. Calcola il consumo di petrolio per le bottiglie di plastica utilizzate:……………………….	a. Calcola l'impronta di carbonio dell'acqua di rubinetto o in bottiglie di plastica usate:……………………………………………………
Lavarsi	a. Acqua consumata per lavarsi e il bagno (lavaggio mani, denti, doccia, sciacquone, ecc…)…………. …………………………….. b. Calcola l'impronta idrica dei flaconi di shampoo/ bagnoschiuma utilizzati:……………………………………………………	a. Calcola il consumo di petrolio per i flaconi di detergenti utilizzati:……………………….	a. Calcola l'impronta di carbonio delle tue docce/bagni in vasca e dei flaconi di detergenti utilizzati:………………………………………………… ……………………………
Mangiare	a. Di un tuo pasto preferito calcola l'impronta idrica:…………………………………………………… …………………………………………………	a. Di un tuo pasto preferito calcola l'impronta ecologica:……………………… ……………………………………… ………………………	a. Di un tuo pasto preferito calcola l'impronta di carbonio:……………………………………… ……
Smartphone e loro uso	a. Impronta idrica del tuo smartphone:	a. Consumo di suolo per produrre il tuo smartphone:	a. Impronta di carbonio del tuo smartphone:…………… b. Impronta di carbonio delle tue chiamate/messaggi/ricerche sul web:………………………………………
PESO ZAINO ECOLOGICO COMPLESSIVO: TOT ACQUA……………………….+ TOT SUOLO/ PETROLIO:…………………………………….+ TOT CO2 EMESSA:…………………………….			

Fig.3.3 Example of operational sheet.

Didactic Objectives	Educational Objectives
● Knowledge about the Agenda 2030 Goals and its intersection with Geosciences ● Knowledge about the water, carbon and ecological footprint topics ● Awareness about the environmental impact of everyday life actions (drinking, washing, dressing…) both for georesources consumption and for waste production ● Awareness about the 5 R actions: Reduce,Respect, Repaire, Reuse, Recycle	● Learn to cooperate and work in team ● Use of mathematician competences for real-task in environmental education ● Think critically about environmental impact of daily habits ● Change behaviours in a eco-friendly manner, following the Agenda 2030 Goals

Tab. 3.3 Description of the didactic and educational objectives of the daily ecological rucksack activity.

At the end, each group calculated the weight of their own daily ecological rucksack, considering the total carbon, water and ecological footprint of all the actions. The ratio between the weight of groups' ecological rucksack and the weight of a reference sample was calculated. The reference sample is a simple rucksack filled up with a bottle of water (1 litre), a package of soil (1 Kg) and a package of cement (1Kg) to simulate CO_2 emission in the atmosphere. This practical approach allowed them to verify directly how much human actions make the ecological rucksack “heavy” in terms of environmental impact.

In phase 7 students were invited to compose the “Sustainability tree”, as an authentic assignment to carry out in the following days. Pupils, in fact, were encouraged to take action towards sustainability in their everyday life, documenting their eco-friendly behaviors with photos. The “Sustainability tree” is a cardboard poster in the shape of a tree, where students could attach their photos of simple sustainable actions they carried out. The tree symbolizes the hope of a transformation process that could be realized first by young people. The teachers of the different courses were invited to cooperate with students in order to reach this task and discuss the value of their changes of mind, to encourage them to also become agents of change in their class, family, environment.

The last part of the activity was carried out using a puzzle-game and a team challenge, called “Reduce your footprint” (Fig.3.4).

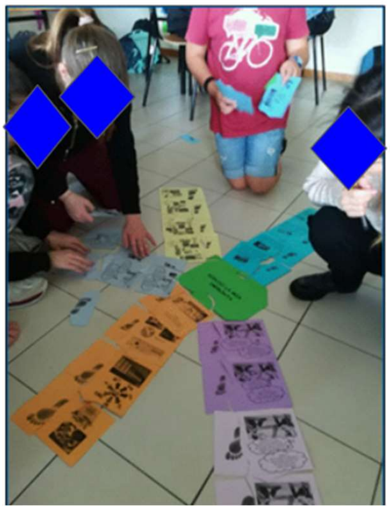

Fig.3.4. “Reduce your footprint activity”.

The teams of 4-5 players were asked to join the pieces of a puzzle representing everyday life actions with the corresponding ecological footprint picture, from the biggest to the smallest one. The daily actions represented were divided into five categories: washing, using smartphones, dressing, eating, shopping in a supermarket. The team's objective was to compose their own part of the puzzle correctly, to reach the goal piece called “Reduce your footprint”. The winning team was the faster one.

3.1.2- Activity B Responsible food consumption

"*How much Earth is on my plate*?" is a learning-by-doing and cooperative learning activity about the ecological footprint of food. The activity is a team-challenge game achievable using raw materials and ready-to-use tools (sheets, boards, pictures, photos). The experimentation was carried out with the same 45 students of the previous activity (see paragraph 3.1), one year later (k-7 pupils) and in the presence of Science teachers. The researcher explained the project to the team class-teachers in advance, in order to allow them to give pupils an introduction about topics linked with the activity. In fact, before the experimentation, Science and Technology teachers had already discussed with pupils subjects such as food nutrient principles and healthy diet. "*How much Earth is on my plate?*" focuses on the environmental impact of food production and consumption, aimed to make pupils conscious that a diet richer in local vegetables and fruits, legumes and cereals than in meat (especially red meat) is healthy both for humans and for Earth.

The project structure is represented in Fig.3.5.

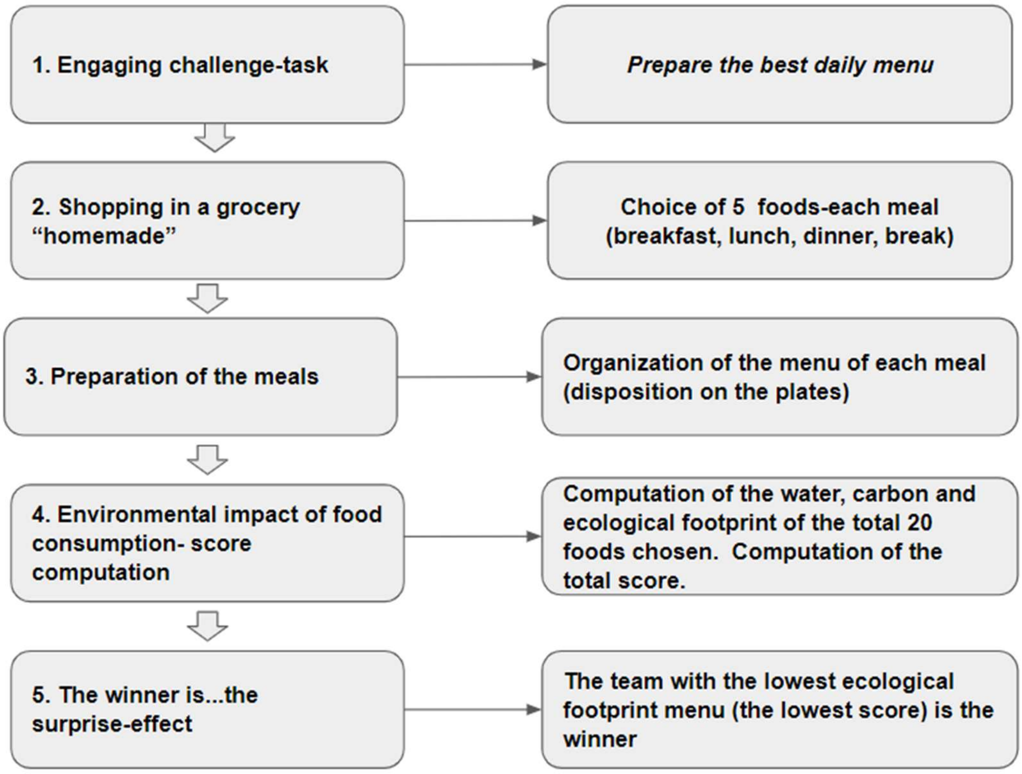

Fig.3.5. "How much Earth is on my plate?" activity

In Table 3.4, a description of "How much Earth is on my plate" activity is reported.

<table>
<tr><td colspan="5">Preliminary step: Pre-activity questionnaire to evaluate pupils' environmental and sustainability awareness</td></tr>
<tr><th>Phases</th><th>Timeline</th><th>Description</th><th>Didactic Objectives</th><th>Educational Objectives</th></tr>
<tr><td>1. Teams creating - Engaging task</td><td>10 minutes</td><td>The class is divided into 4-player teams. The researcher engages pupils asking them to prepare a daily menu composed by food products they prefer.</td><td rowspan="7">● Awareness about the environmental impact of food production and consumption
● Awareness about the big amount of natural resources used to produce food
● Comprehend how an healthy diet for humans is healthy for Earth tool</td><td rowspan="7">● Learn to cooperate and work in team
● Use of mathematician competences for real-task in environmental education
● Think critically about environmental impact of food production and consumption
● Change behaviours in a eco-friendly manner, towards responsible consumption choices</td></tr>
<tr><td>2. Shopping in a grocery</td><td>20 minutes</td><td>Teams choose 5 foods for each daily meal, taking from a collection of several products pictures.</td></tr>
<tr><td>3. Plating foods</td><td>5 minutes</td><td>Teams put pictures on the cardboard plates, composing four meals (breakfast, lunch, break, dinner).</td></tr>
<tr><td>4. Environmental impact of food consumption</td><td>60 minutes</td><td>Computation of water, carbon and ecological footprint of each meal</td></tr>
<tr><td>5. Score computation</td><td>5 minutes</td><td>Students consult reference sheets in order to calculate the score game.</td></tr>
<tr><td>6. The winner is...</td><td>2 minutes</td><td>The researcher proclaims the winner: the team with the lowest score</td></tr>
<tr><td>7. Discussion</td><td>20 minutes</td><td>Discussion about the activity and the factors that influence the ecological footprint of food.</td></tr>
<tr><td colspan="4">Final step: Post-activity questionnaire + satisfaction questionnaire</td><td></td></tr>
</table>

Tab. 3.4. Description of "How much Earth is on my plate" activity.

At the beginning of the activity, pupils were given a questionnaire, composed both by a series of statements to rank with Likert scale and by open-answer questions about Sustainable Development and aware food consumption, to evaluate their familiarity with these topics. A 5-levels Likert scale was used to rate the agreement/disagreement on specific items. The same questionnaire was administered at the end of the activities to evaluate the didactic outcomes. Finally, pupils filled out a satisfaction questionnaire in order to think critically about the activity proposed.

The gaming-challenge approach allows students to engage and enjoy themselves, increasing their own awareness about Geoscience topics such as natural resources (water and soil) exploitation and the carbon footprint due to food production and consumption. The activity was tested with 45 K7 students, but it is easily adaptable to younger or older students (K6-K8). Pupils were invited to do a simulated grocery shopping using a home-made market (Fig. 3.5). A collection of photos representing common food products was selected and divided into categories: meat, fish, vegetables, fruits, cereals, legumes and cakes. The researcher chose, within each food category, different types of products (Italian/ foreign, local/no local, Bio/no Bio, packaged/unpackaged…), in order to highlight their different environmental impact. Pupils were divided into 4-players teams that were invited to accomplish a task-challenge: *Prepare the best daily menu.* The aim of the challenge was to organize 4 daily meals (breakfast, lunch, break and dinner) in the best possible way, following the players' tastes and preferences. For this aim, each team had to choose five food photos for each meal and then put them on the cardboard table (Fig.3.6). Then, a team work followed: pupils had to calculate the water, carbon and ecological footprint of the chosen products, analyzing labels (Fig.3.7) and packaging and using reference and operational sheets.

Fig.3.6. Pupils shopping in the home-made grocery.

Fig.3.7. Example of food photos and labels.

As in every challenge-game, players collect a score. In this case, a symbolic score was associated with each food product, in relationship with its environmental impact. The score, in fact, depends on the ecological footprint, origin, kind of packaging and quality of the product (biological, equo-solidale …). The higher the environmental impact, the higher the score is obtained. The teams had to calculate their own score using the sheets and then communicate to the others. As a surprise effect, students discovered that, unusually, the winning team is the one that collects the lowest score, i.e. the lowest environmental impact. A final discussion allowed groups to think critically about their consumption habits and choices.

3.1.3 Activity C (Sustainability through gaming)-Sustainable City Game activity

The Sustainable City game is an engaging ludic activity to be played in teams or individually, planned for 11-14 years old students. In fact, the difficulty level of the questions and tasks proposed can change depending on the classes. This activity could be easily adapted also to be used with younger and older students (aged 10 and 15) as a related activity to the vertical curriculum (Indicazioni nazionali, 2012). The S-City Game project sparks student's interest about Sustainable Development topics in the frame of Agenda 2030. The game is multidisciplinary, since it involves several matters in order to promote students' knowledge and expertises in an interdisciplinary manner, following an holistic path. Geography, Science, Technology, History, Math and Citizenship Education topics linked with Sustainable Development and sustainable use of georesources are key-concepts of the Activity C. The game tests to pass are about topics such as Georesources exploitation, circular economy, sustainable lifestyles and responsible consumption and production. The description of the S-City Game in the two versions follows.

-3.1.3.1 Activity C1- The Sustainable City Game-cardboard version

Activity C1 is an activity based on a board game similar to the Game of the Goose, with a series of boxes corresponding to several tasks and multidisciplinary questions. *Sustainable City Game*"-cardboard version activity is divided into 6 phases (Tab. 3.5), with a brief introduction about the main topics of Agenda 2030 Goals. All the game equipment was realized using raw materials.

Phases	Timeline	Description	Didactic Objectives	Educational Objectives
1.Introduction	10 min	The researcher introduces the game, reminding the most significant Agenda 2030 topics	• Knowledge about Agenda 2030 Goals and targets • Awareness about the natural resources consumption • Awareness about the interdisciplinarity of Sustainable Development topics • Comprehend the environmental impact of humans lifestyles • Awareness about sustainable daily actions	• Learn to cooperate and work in team • Learn to game for good competition • Use of multidisciplinary competencies to overcome tasks • Think critically about environmental impact of daily habits • Change behaviours in a eco-friendly manner, following the Agenda 2030 Goals
2. Teams formation + SDGs choice	5 min	Students are divided in 4-players-teams that should be heterogeneous with the help of class teachers. Each team choose one of the 17 SDGs to adopt		
3.Gaming	60 min	Teams play overcoming several interdisciplinary quizzes and tasks		
4.Final challenge	15 min	All teams plan an electoral campaign to defend the adopted Agenda 2030 Goal		
5.The final ranking	5 min	Students and teachers discuss the final challenge performances. They agree the final ranking		
6.Final discussion	10 min	Discussion about the activity and difficult topics emerged by gaming		
Final step: *Satisfaction questionnaire*				

Tab.3.5. Description of “Sustainable City Game” -cardboard version activity

Each checker represents one of the 17 SDGs and teams (3-4 players) have to choose one of them, in order to “adopt” that Goal. Players have to roll the dice and advance with the checker on the basis of the score obtained. Different boxes correspond to different tasks: if the team overcomes the task, it can go on three boxes, otherwise it stops.

The experimentation was conducted both on teachers first, during V Geoscience Summer School (2019) in Camerino, and then on 112 students from several schools of the Marche Region. The experimentation with teachers allowed the researcher to first test the game performance, involvement and satisfaction degree of players.

-Experimentation with teachers

The S-City game cardboard version was first experimented with 24 teachers, from Primary, Middle and High School. They played individually with the researcher’s supervision (Fig. 3.8).

Fig. 3.8. S-City Game experimentation with teachers.

At the end of activity, teachers were given a satisfaction questionnaire, composed both by a series of statements to rank with Likert scale and by open-answer questions. This investigating tool allowed to highlight the strengths and weaknesses of S-City Game and to think critically about possible solutions for overcoming weaknesses. Examples of statements or questions teachers' were supposed to rank or answer are the following: "Have you ever discussed the Agenda 2030 with your students? In which occasion?", "The Agenda 2030 topic is interesting and I'd implement this issue with my pupils after this activity", "The educational game S-City Game is a good approach to deal with Agenda 2030 goals topic", "Express your opinion about the strengths and the weaknesses of the activity". Teachers were also invited to write other suggestions for game improvement.

-Experimentation with students

The following experimentations were carried out with students (totally 112), from several schools of the Marche region (Fig.3.9).

Fig. 3.9. S-City Game experimentation with students.

The activity was tested in the presence of both researcher and class teachers of different subjects (Geography, Science and Technology, depending on classes) with the role of proactive observers and helpers during the activity. Pupils played in 4-players-teams, since four is the suitable number for working in small groups. As already explained for activity A, the groups' formation was delegated to class teachers because of their familiarity with pupils and dynamics of the class. The teachers set up heterogeneous groups.

In each session of the game experimentation, the researcher carefully observed and noted students' attitude and engagement, in order to highlight the game strengths and weaknesses. These observations aimed to gather information for future game improvements. For example, students got bored, losing enthusiasm and motivation, when the play time was stopped, even for a few minutes for explanations or discussions about new topics. Furthermore, the use of a timer improved students' concentration during the game as well as the discussions-time, moving it at the end of the activity, avoiding interruptions.
The rules of team-to-team challenges were also changed: in the first version of the game, only two teams could play. Then, the other teams were involved too, to get one game-point. In this way, all students can feel involved as much as possible, avoiding dead-times during the gaming.

At the end of the game, pupils were encouraged to debate and reflect on responsible lifestyle in order to become aware citizens, also thanks to the final challenge that promotes critical thinking about action-maker attitudes. At the end of the activity students were given a satisfaction questionnaire, composed both by a series of statements to rank with Likert scale and by open-answer questions. The following statements were in pupils' questionnaire: "The Agenda 2030 topics are involving", "I enjoyed S-City as an educational game", "I would like to use an educational game to address also different topics and subjects", "Write particular aspect/s of this activity you like the most", "Write particular aspect/s of this activity you would like to change".

-3.1.3.2. Activity C2. "Sustainable City Game"- virtual version activity

The S-City Game digital version project started during the 3rd year of my PhD, in collaboration with my colleague Michelina Occhioni, a PhD student attending the second year of School of Advanced Studies (Geology Department, tutor prof. Eleonora Paris). In fact, the digital game is a part of a wider project which includes the creation of a virtual island, Sustainability Hub, devoted to Sustainability topics. The digital version of the game has been created in a virtual world based on the 3D Opensimulator platform that can be accessed by teachers and students as avatars. The S-City Game has been transformed into a digital version, through the change of some aspects that made it more suitable for the digital tool. In the virtual version of the game the avatars/players are the pawns of the game and wear a hat marked with the chosen SDG. The avatars move on the board and click on the landing box to start every task. Through an interactive panel and text chat, players can answer the questions or accomplish tasks. Some tests of the game are carried out using online educational apps, or sharing online interactive whiteboards. The experimentation was carried out both on teachers and students.

-Experimentation with teachers

S-City virtual Game has been tested with 24 teachers from Middle school. Most teachers (83.3%) were not familiar with virtual worlds, so an initial training to master how to move and interact was necessary. During this phase, teachers acquired the basic skills to use their own avatar and interact with virtual objects. Teachers were given a questionnaire that investigates: if and how they have ever addressed their pupils to the Agenda 2030 topics; their level of satisfaction about the proposed activity; eventual suggestions to improve the game. Both teachers' and students' questionnaires were composed of a series of statements to rank with a 5-point Likert scale and by open-answer questions to highlight strengths and weaknesses in the activities.

-Experimentation with students

The activity was tested with 69 k6-k8 students (Fig. 3.10).

Fig.3.10. Students playing S-City Virtual Game.

They, unlike teachers, didn't need a lot of explanations to move in the world because of their better familiarity with digital games and the virtual world. Students were given pre- and post-activity tests that investigated their familiarity with the Agenda 2030 topics and their involvement and satisfaction degree during the game. Students were asked: to give definitions about some Sustainability topics; express their opinion on the pleasure of overcoming each task of the game, answering the quizzes, working in a team; to stress strengths and weaknesses of this activity in the virtual environment. Pupils' open answers allow us to collect data about their idea of a sustainable city and sustainable lifestyle too.

3.1.4 Activity D (Agenda 2030 and Sustainability in virtual worlds)- "Sustainability Hub"

"Sustainability Hub" is an Opensimulator-based virtual island dedicated to Sustainability topics and Agenda 2030 goals (Fig. 3.11).

Fig. 3.11. Overview of the Sustainability Hub island.

This island is situated in Techland, a virtual world focused on math and science subjects for K6-K10 students owned and managed since 2011 by Michelina Occhioni. This project is the result of a team-work: the contents have been realized in collaboration with my colleague who took care of the technical part too.

The main steps of the Sustainability Hub planning are shown in Fig. 3.12.

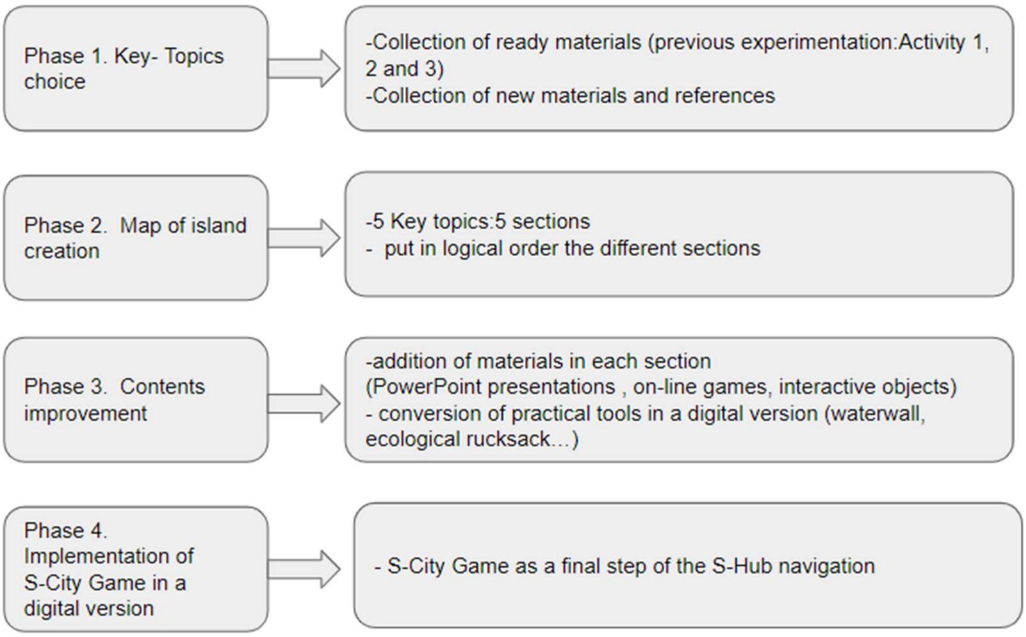

Fig.3.12. Sustainability Hub project phases.

During Phase 1, the key-topics were selected, in order to address the Sustainable Development and its three dimensions (social, economic and environmental), with a particular focus on the environmental one and the sustainable use of georesources. The key topics selected are: the global scenario (environmental and social crises), georesources and waste, the sustainability indicators, the Agenda 2030 and its Goal and targets, the Sustainability pillars.

In order to plan the activity, the ready didactic materials used in the previous experimentations (described in paragraph 3.1.1 and 3.1.2) were collected together as well as new didactic materials (scientific data and bibliography). During Phase 2, the Sustainability Hub island map was realized, creating five sections devoted to the key-topics selected. One of these sections has been devoted to the S-City game. The Sustainability Hub island sections and didactic and educational objectives are summarized in Tab. 3.6.

Section name	Description	Learning objects	Didactic objectives	Educational objectives
The global scenario	A view of some environmental, social and economic global crises: climate change and global warming, loss of biodiversity, global poverty, world population growth.	-PPT presentation -engage questions -interactive graphics - Excel operational sheets - online games - quizzes -interactive panels	-comprehend the urgency of a global transformation toward sustainability -awareness about multidimensional issue of sustainability process	-Learn to work and study with digital tools - Create social cohesion in distance learning - Cooperation and collaboration even remotely -Improve digital skills and competencies
Resources	What is a resource and what is a waste? Water, soil, minerals, fossil fuels, waste from separate collection, electronic waste, organic waste.		-comprehend that everything is a resource, if humans embrace circular economy - awareness about the natural resources value - put in order of importance the 5 Action: Reduce, Respect, Reuse, Repair, Recycle	
The Sustainability indicators	Water, carbon and ecological footprint. Ecological rucksack.		-Awareness about the environmental impact of everyday life actions (drinking, washing, dressing…) both for georesources consumption and for waste production	
The Agenda 2030 Goals	-The road towards Sustainability -The 17 SDGs and and 169 targets Temple of Sustainability (the Three Pillars of Sustainability and the 5-P dimensions) Fig. 4.3. -State of the Art about the achievement of SDGs in Italy and other countries		- Comprehend how many international meetings and agreements preceded the establishment of the Agenda 2030 -Awareness about the multi dimension of Sustainable Development (economic, social and environmental) - Interact with learning objects for addressing the SDGs contents	
The S-City Game	Described in paragraph 3.2			

Tab.3.6. Sustainability Hub sections description.

The researchers planned a sequential path to follow, starting from Section 1 to Section 5 (Tab.3.6), but pupils could explore randomly too. Then, each section was enriched with contents, learning materials and interactive objects (Phase 3). In this phase some practical didactic materials (related to Activity 1, Activity 2, Activity 3.1) were converted in a digital format and placed in the corresponding section. During phase 4, the digital version of S-City Game was completed. The Game represents a sort of final step of the island navigation that allows teachers to summarize with students the topics they had addressed during the Sustainability hub exploration.

The experimentation has been carried out both with teachers and students (2 hours every time) (Fig.3.13).

Fig. 3.13. Students challenge themselves with S-City Hub quizzes.

The activity was tested in sharing-screen mode or in-world mode depending on the digital tools availability in the schools involved in the project. A preliminary study aimed at 21 teachers of various disciplines of primary, middle and high school, was accomplished, to verify the interest of the teachers for this type of educational activity and to improve the hub following also their suggestions. Teachers' satisfaction questionnaire was administered in order to highlight the strengths and the weaknesses of the project. In this PhD thesis the data experimentation with teachers will be shown and discussed. On the other hand, the experimentation with students will be deeply analyzed and discussed in Michelina Occhioni PhD thesis.

3.2. Data analysis

The experimentation results have been analyzed using a methodological approach consisting of a combination of quantitative and qualitative data analysis. These two approaches relate respectively to the experimental positivist paradigm and to methodological constructivism (Vygotsky,1962). Combining and integrating the qualitative and quantitative analysis of the collected data is a crucial point. In fact, all the learning process is not only an evaluation of a student's product (right/wrong quiz answers), but also a mix of identifying, guiding and following the pupils' mental process. Therefore, it becomes important to understand the students' reasoning to get to their answers and how these answers were formulated and expressed. Tab. 3.7 shows the main differences between quantitative and qualitative analysis.

QUANTITATIVE ANALYSIS	QUALITATIVE ANALYSIS
● Defining of the search field, starting from the existing literature ● The data are converted into a measurable form and collected through multiple-choice questions, scores on a scale etc. ● The data are in a numeric form and analyzed using statistical tools ● The data are objective.	● Each research context is unique and specific ● Descriptions or free answers through open-answer questionnaires, interviews, focus groups… ● The collected data consist of texts analyzed with rubrics or software such as Nvivo and Atlas.ti. ● The data are subjective.
QUANTITATIVE TOOLS	**QUALITATIVE TOOLS**
● Data collection on a large sample ● The ultimate purpose of the analysis is the initial assumption validation ● The analysis is generalizable ● Questionnaires, scales ratings, checklists for systematic observations	● Collection of data on a restricted and selected sample: case study ● Exploratory purpose ● Deepening of subjective experiences ● Interviews, rubrics, systematic observations

Tab. 3.7. Main differences between quantitative analysis and qualitative analysis (Coggi, 2005).

The quantitative analysis has been carried out using the Likert scale. This is one of the most reliable methods to measure attitudes and behaviors, through several answer options, ranging from one extreme to another (for example, from *completely disagree* to *completely agree*). This method allows the researcher to discover the different degrees of judgment. The questionnaire is a widely used tool for the evaluation of the activities of a project, of an educational path, of a real life experience. The questions addressed to pupils have been formulated carefully, in order to draw attention and to vehicle the exact meaning of the information requested. In Fig. 3.14 the scheme of the activities tested using a quantitative analysis is represented.

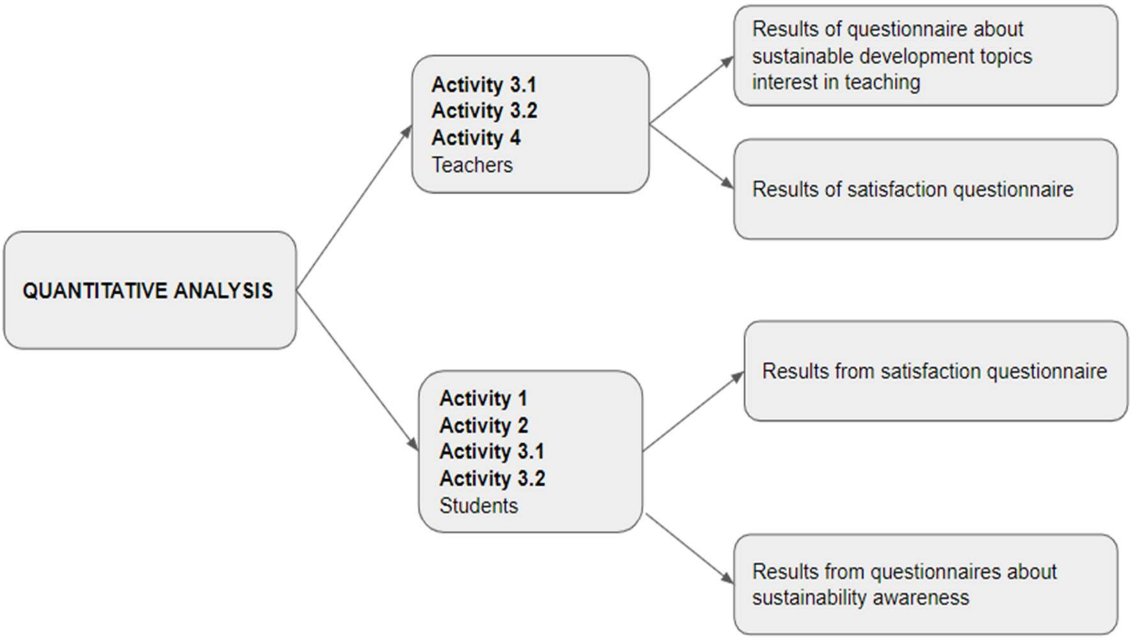

Figure 3.14. Scheme of data experimentation studied using quantitative analysis.

The Qualitative analysis has been carried out using an evaluation rubric. Rubrics are useful tools for systematic observations as Ellerani claims (2013): "It is possible to define them as a tool to list the criteria that should inspire the assessment of competence and its size. Similarly they may become a guide for the evaluation of the products covered by the expert task... The heading is a set of criteria consistent to assess work, skills and students, which includes descriptions of levels, of quality of the competences articulated through specific criteria... The heading clearly expresses the quality levels for each dimension of competence deemed necessary to be assessed". An evaluation rubric is an instrument in the form of a double entry table where the criteria and qualitative levels of a certain task or performance required of pupils are given. It is a relatively objective tool that allows students to know what is expected in every activity, making them more aware and involved in their own learning process (Varisco, 2004). The following steps had to be taken into account when creating an evaluation rubric:

- Choosing the task to be addressed.
- Select the important contents or abilities of the unit and clearly decide what you want to evaluate and then circumscribe the performance subject of the evaluation section.

- Describe the assessment criteria specific to each area or task.
- Describe a scale of criteria ranging from the highest to the lowest.

As reported in the literature (Dare, 2013; Rhodes, 2010) the rubrics aim not to identify a score or a final grade, but to describe a performance and highlight whether and how the goals previously established have been achieved, paying particular attention to the level of mastery. It is therefore a general evaluation tool used to assess the quality not only of products, but also of processes in a given area (Stevens, 2012).

The structuring of rubrics allows an evaluation of authentic and dynamic skills (Tessaro, 2015) in its broadest sense:

- Multidimensional, because it is not reduced only to a single objective;
- Predictive, because it evaluates complex tasks and performances, useful and meaningful also for pupils' educational future perspectives;
- Advantageous for students who, knowing the teacher's expectations, perform with greater awareness concrete tasks in real situations. Thanks to the type of task students are required to activate constructive thinking processes. This assessment makes the pupils more aware of their limits, abilities and levels of learning.

In Fig. 3.15, the qualitative analysis carried out in this PhD thesis is described.

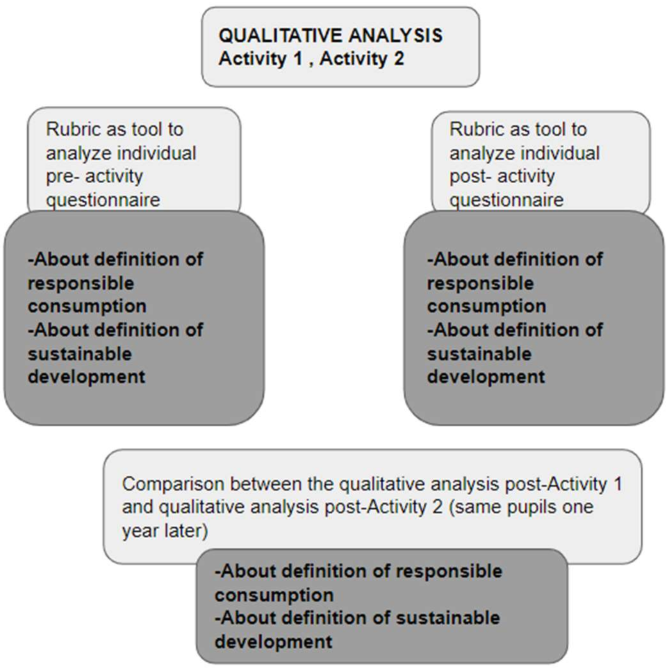

Fig. 3.15. Scheme of data experimentation studied using qualitative analysis.

The experimentation of Activity A and Activity B on the same pupils (Activity B one year later) allowed the researcher to test if there had been an improvement of sustainability awareness during the time, thanks to a didactic reinforcement. To collect data, evaluation rubrics were used. The elaboration of all levels takes inspiration from the PhD thesis of my colleague who worked in a project about Education for Sustainability too (Stacchiotti, 2019 a). According to Stacchiotti (2019), these evaluation rubrics are effective tools to conduct a qualitative data analysis on open-ended questions about sustainability topics.

Tab. 3.8 shows the description of levels in a general manner, while tab.3.9 and tab. 3.10 describes the different levels specifically related to pupils' definitions of Sustainable Development and responsible consumption.

LEVEL	**Description**
LEVEL A (*Elaborated*)	Excellent (9-10) Completely correct definition; specific and elaborated language
LEVEL B *(Intermediate)*	Good (8) Mainly correct definition; specific language
LEVEL C *(Essential)*	Sufficient (6-7) Definition based mostly on practical examples. Simplified language
LEVEL D *(Missing)*	Not sufficient (5) Lack of a definition; completely incorrect definition.

Tab. 3.8. Evaluation rubric for qualitative analysis.

LEVEL	**DESCRIPTION**
LEVEL A (*Elaborated*)	The student gives the completely correct definition of Sustainable Development, considering all its pillars (environmental, social and economic). There is the action component in the definition. Specific and elaborated language.
LEVEL B (*Intermediate*)	The student gives a quite correct definition of Sustainable Development, considering at least one or two aspects of it.There is the action component in the definition. Specific language.
LEVEL C (*Essential*)	The student uses some practical examples of daily routine to explain the concept of responsible consumption. Simplified language.
LEVEL D (*Missing*)	No answer or completely incorrect answer.

Tab. 3.9 Evaluation rubric with description of all levels about students' definitions of Sustainable Development.

LEVEL	**Description**
LEVEL A (*Elaborated*)	The student gives the completely correct definition of responsible consumption, considering multiple aspects of it. There is the action component in the definition. Specific and elaborated language.
LEVEL B *(Intermediate)*	The student gives a quite correct definition of responsible consumption, considering at least one or two aspects of it. There is the action component in the definition. Specific language.
LEVEL C *(Essential)*	The student uses some practical examples of daily routine to explain the concept of responsible consumption. Simplified language.
LEVEL D *(Missing)*	The student doesn't give any answer/ gives a completely incorrect answer. Very generic and banal language.

Tab. 3.10. Evaluation rubric specific for the open-ended question about the definition of responsible consumption.

4- RESULTS

4.1 Introduction to results

In this chapter the results obtained by this research experimentations about Sustainability are reported and analyzed. Tab. 4.1 summarizes all the activities carried out and related publications. These works are grouped according to their corresponding activities tested. The table also shows the date, the kind of publication (poster or paper), the Conference, and the reference link of each publication.

As explained in Chapter 3, Activity 0 was a preliminary study on hands-on didactic activities in Geosciences, focusing on earthquakes and seismic risk. Tab. 4.1 shows the titles and references of two posters published in conference proceedings that explained the experimentation results. Although these activities have been useful to approach Geoscience topics using learning-by-doing methodology, the details and results are not reported in this PhD thesis. In fact, they don't concern the specific topic of this project that is Sustainability. Their experimentation anyway has been useful to draw inspiration for the following didactic laboratorial activities.

In this chapter full-text articles follow, presenting the results obtained during the experimentations and illustrating some of the most significant aspects of the research, using cooperative learning, learning-by-doing and learning-by-gaming approaches as methods to vehicle sustainability topics in an interdisciplinary way. Therefore, the following paragraphs report articles, published for each activity carried out during this research.

Regarding **Activity A** *Georesources, waste and footprints*, two papers are presented (see par. 4.2.1 and par.4.2.2). Similarly, **Activity D** *Agenda 2030 and Sustainability in virtual worlds* is described in two different articles (par.4.6.1 and 4.6.2). In par. 4.7 the results regarding the definition of Sustainable Development and Responsible consumption are reported (qualitative analysis).

ACTIVITY	TITLE	YEAR	KIND	CONFERENCE	LINK
Activity 0 Geoscience through integrated learning (par.4.1)	"*I will not crumble: the earthquake among science, poetry, technology and music*"	2019	Poster	EGU Gift Vienna	https://meetingorganizer.copernicus.org/EGU2019/EGU2019-16815.pdf
	"*The earthquake among science, poetry, technology and music: an integrated learning activity*"	2019	Poster	ESERA Conference (Bologna)	https://www.dropbox.com/s/0kl4vmx3arf5eft/ESERA2019_ok.pdf?dl=0
Activity A Georesources, waste and footprints	"*WASTEBERG: a didactic activity about waste and sustainable use of georesources in relation to the Agenda 2030*" (par.4.2.1)	2019	Paper		ROL Vol. 49, pp. 127-133 https://doi.org/10.3301/ROL.2019.62
	"*Engaging didactic activities to disseminate sustainability-topics among students as agents of change for a more sustainable world*". (par.4.2.2)	2020	Virtual presentation	ICERI 2020	https://library.iated.org/view/BECCACECI2020ENG
Activity B Responsible food consumption	"*How much Earth is on my plate?" A special challenge-game to evaluate foods' ecological footprint*" (par.4.3)	2022	Paper	In press	
Activity C1 Sustainability through gaming	"*Sustainable City Game: an engaging cardboard game to address students to Agenda 2030 Goals for Sustainable Development*" (par.4).		Paper	In press	
Activity C1 Sustainability through virtual gaming	"*Sustainable city virtual game: how to engage students in sustainable lifestyles*" (par.4.5)		Paper	In press	
Activity D Agenda 2030 and Sustainability in virtual worlds	"*Teaching sustainability and agenda 2030 topics in virtual worlds*" (par.4.6.1)	2021	Virtual presentation	EDULEARN	https://library.iated.org/view/
	"*Teaching sustainability topics in virtual worlds. A preliminary study.*"(par.4.6.2)	2021		ESERA 2021	https://docs.google.com/document/d/1WBPgLZsyHJcqqbJxO4Nsra5vsxk10X5h

Tab. 4.1. Summary of this PhD research publications.

4.2. Activity A- Georesources, waste and footprints.

In this paragraph two papers about Activity A topics follow. The research group Unicam Earth has been working on the themes of environmental education for a long time. Therefore, at the beginning of my doctoral programme, I participated in other didactic experimentation about Sustainability, in particular to the one called "Wasteberg Activity". I cooperated in testing this laboratorial didactic experience, based on the IBSE approach, and the results obtained are reported in the paper included in par. 4.2.1.

The second paper, shown in par. 4.2.2, describes "The daily ecological rucksack" activity. This project can be considered as a follow-up work, because it took inspiration from the previous one (Wasteberg activity). Therefore, the collaboration with other doctoral students who have preceded me has been very precious for my work, thanks to several points of reflection and the competences I acquired.

In both articles the numbering of all tables and figures is the original one, as appears in the publication.

4.2.1. Wasteberg activity

The aim of the activity is to make the students understand that, by taking into consideration different types of packaging wastes, what is beyond common household wastes can be graphically represented by the shape of an iceberg, called "Wasteberg". This name was firstly introduced by Young and Sachs (1994), to describe the idea that for every one pound of waste we generate directly, 70 pounds of waste are generated upstream. A practical representation of the Wasteberg was used to create a teaching activity for k-8 students with the aim to connect the study of geomaterials to the concept of Sustainable Development.

Rend. Online Soc. Geol. It., Vol. 49 (2019), pp. 127-133, 4 figs. (https://doi.org/10.3301/ROL.2019.62)

WASTEBERG: a didactic activity about waste and sustainable use of georesources in relation to the Agenda 2030

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ABSTRACT

Nowadays, the Agenda 2030 for Sustainable Development is a key concept to be introduced in the Environmental Education at all school levels. Therefore, it is important that Science Curricula will be integrated with didactic paths, in order to make students approach the topics of the Agenda, making them easier to understand and suitable to be treated in classes of different grades.

Geosciences can offer fruitful opportunities for the realization of many multidisciplinary teaching activities related to the Sustainable Development. Here we present a didactic activity about waste and circular economy, in line with Agenda 2030, which has been realized for 14-years-old students and tested both in the class and with a group of teachers. In the activity, topics like georesources, ore deposits, mining are approached, to explain the life cycle of packaging materials. The Wasteberg, a term firstly introduced by Young and Sachs (1994), was used here to name the activity, which was implemented from to the original concept to build an articulated didactic plan. By taking into consideration different types of packaging wastes, made of aluminum, glass, plastics and paper, the aim of the activity is to make the students understand that what is beyond common household waste can be represented by the shape of an iceberg. By using a familiar comparison, the objective of the activity was to attract the interest of students, increasing their understanding and awareness about non-renewable resources and sustainable development, by making them focus on resources consumption and the energy flow behind any productive processes.

Pupils, divided in groups, worked following the Inquiry Based Science Education approach (IBSE). The activity was carried out using also interdisciplinary aspects, involving in the experience the teachers of math, history, geography and technology. As a final outcome, the class determined the economic and environmental advantages that can be obtained by recycling waste materials.

KEYWORDS: Agenda 2030, teaching Geosciences, sustainable development, environmental awareness.

INTRODUCTION

Environmental Education at school is highly relevant to help face the problems of society and also to address the pupils' need to understand the major environmental topics affecting the world. Tillbury (1995) declares that Environmental Education is also a tool for improving critical thinking that allows pupils to become aware and active citizens. Nowadays, Education for Sustainability is a key concept in the Environmental Education and should be a high priority at all school levels. It also adds relevance to the curriculum (Gayford, 1991), since environmental, economic and social problems undermine the future of humanity on Earth. Children should be educated and trained to become literate citizens with shared responsibilities towards the environment and their fellow humans (Davis, 2009). Sustainable living must be the new pattern for all levels: individuals, communities, nations and the world. Adopting the new pattern will require a significant change in attitudes and practices of many people starting from families and schools. Therefore, the school curricula should communicate the importance of a more sustainable living (IUCN/UNEP/WWF, 1991). Since environmental and development problems are not simply caused by physical and biological factors, a comprehensive understanding of the parts played by social, economic, political, historical and cultural elements is required (UNESCO, 1992). In fact, the investigation of any environmental issue must involve the study of the intersection and interaction of these components, using holism as its philosophical basis and multidisciplinarity, to be used in the curricula, to deal with these topics on a daily basis at school.

The topics of the Agenda have been included in the teaching of Environmental Education for the Italian 11-14 years old students (Indicazioni Nazionali, 2018), calling for ways to approach the themes highlighted in it. In fact, "*…this Agenda is a plan of action for people, planet and prosperity……Its 17 Sustainable Development Goals and 169 targets ... will stimulate action over the next fifteen years in areas of critical importance for humanity and the planet: the determination to protect the planet from degradation, including through sustainable consumption and production, sustainably managing its natural resources and taking urgent action on climate change, so that it can support the needs of the present and future generations… All countries and all stakeholders, acting in collaborative partnership, will implement this plan… The 17 Sustainable Development Goals. demonstrate the scale and ambition of this new universal Agenda… They are integrated and indivisible and balance the three dimensions of sustainable development: the economic, social and environmental. The Goals and targets will stimulate action over the next 15 years in areas of critical importance for humanity and the planet.*"

(https://www.unric.org/it/agenda-2030). Geosciences are, among the natural sciences, those that can intersect most with the topics of the Agenda 2030 [17 Topics in total], not only those directly related to Earth sciences such as [6] clean water and sanitation, [7] affordable and clean energy, [13] climate action, [12] responsible consumption and production, [15] life on land, but also others such as [11] sustainable cities and communities, [1] no poverty, [2] zero hunger [4] and quality education. Practically, there is a possibility of overlapping with the large majority of the Agenda topics, which opens many possibilities to create paths to link them to geoscience topics, offering and integrated approach to sustainability.

Unfortunately, Geosciences are still poorly addressed in Italian schools, as evidenced by a number of authors (see among others, Realdon et al., 2016; Lancellotti et al., 2016). In particular, topics such as geomaterials (rocks and minerals, their properties and utilization) but also the concept of georesources (for energy or extraction of industrial or critical minerals) are usually taught only in a mnemonic way, without linking them to everyday life and often disregarded as not very important even by the science teachers. Conversely, Geosciences allow instead many connections with other subjects, thanks to the possibility to link different disciplines (chemistry, biology, physics, technology…) through interdisciplinary topics. The exploitation, use and sustainable consumption of georesources offer ample possibilities to approach many modern and actual subjects and issues, which can involve the students' everyday life with an attention to the territory where they live in.

The name "Wasteberg" was firstly introduced by Young and Sachs (1994), to describe the idea that for every one pound of waste we generate directly, there are 70 pounds of waste generated upstream. Therefore, to better visualize this concept, this idea was related to the shape of an iceberg with the underwater part much larger than the emerged part. A practical representation of the Wasteberg was used here to create a teaching activity for 14-year-old students with the aim to connect the study of geomaterials to the concept of Sustainable Development.

Teaching Sustainable Development is not about preparing students for a world that is static and fixed, but it concerns getting students ready to cope with changes and challenges in their lives. Traditional direct instruction focuses on mastery of content with less emphasis on the development of scientific skills and attitudes: students are the receivers while the teacher the dispenser. Conversely a more meaningful science learning could be achieved via the use of the Inquiry-Based Science teaching approach (Shamsudin et al., 2013), which is the didactic approach used in this experimentation. IBSE has been chosen also because it is an educational approach recommended by the European Union for the teaching of the experimental sciences (Rocard, 2007). Its use is closely linked to the development of skills related to the understanding and the use of scientific research methods. The direct experience of the Inquiry, as well as every learner-centered approach, has the advantage of being more engaging for students and, therefore, to increase their attention and involvement. Inquiry-based teaching, besides to have positive effects of interest and motivation, can be effective both with weaker or less motivated students, and for the strengthening excellence. Nevertheless, IBSE remains an exception among the methods adopted in Italian schools, especially at the Middle school level (11-to-14 years-old students) for problems related to its use, mainly the limited time available during teaching hours, but also for the time necessary to plan and organize the activity, and in general because many teachers still do not know IBSE sufficiently to feel confident in prepare a lesson using it. In preparing the activity proposed here, priority has been given to practices in Geoscience teaching to respond to the diverse needs of children and their different learning styles, so teachers can help students to learn more effectively than they otherwise would. Problem-based inquiry process, hands-on/minds-on activities, team-work, individual work on open-ended questions, trans-disciplinary activities (e.g. Maraffi et al., 2016) all go in this direction and have been used here.

In the frame of the proposed activity, students were also encouraged to initiate discussions on the environmental topics addressed in school with the adults at home and in their community, since it is recognized that pupils might act as catalysts of environmental communication and learning beyond school boundaries (Ballantyne, 2006). Finally, the didactic activity was planned to verify if a geoscience-related activity could improve the interest in Geoscience and Agenda 2030 topics, and could also indirectly contribute in improving the scientific and mathematic competences of the pupils using a practical application.

The Wasteberg activity was also tested on groups of teachers, to verify its effectiveness and collect criticisms and useful suggestions. It was also used to investigate if the activity proposed was of interest for their teaching styles and to understand if the science teachers without a geological background could find at ease in approaching such topics. In fact, already available and ready to use didactic tools can make the activity itself easier to be carried out and more appealing to be proposed at schools, such as teachers' and students' forms already prepared, cheap materials easily assembled, a guide to the activity and hints for multidisciplinary links and follow-ups topics.

In the following, we will we focus on the activity at school and the results obtained, but some useful comments from the teachers involved in the testing will be discussed.

MATERIALS AND METHODS

The IBSE approach contributes to students' understanding phenomena in an in-depth and effectively way, stimulating also problem-solving competences. The IBSE approach is structured into the 5Es phases, such as Engage, Explore, Explain, Elaborate and Evaluate: in this activity this structure was followed by carrying out a 2-hours activity, divided in different parts, where different competences were required and a combination of didactic approaches were used.

At the beginning, pupils were given a questionnaire, composed both by a series of statements to rank with Likert scale and by open-answer questions about the concept of Sustainable Development to evaluate their familiarity with the topic. A 5 levels Likert scale was used to rate the agreement/disagreement on specific items. The same questionnaire was administered at the end of the activity to evaluate the didactic outcomes. We report here some examples of statements or questions pupils were supposed to rank or answer: *"Pollution is a global issue", "Waste is a resource", "What is the difference between Reuse and Recycle?", "What is Sustainable Development?", "Try to explain how a waste could be converted into a resource"*. The post-activity questionnaire also included some self-assessment and reflection questions, useful to evaluate the change of attitude towards waste and environmental problems: *"I was engaged during the activity", "The provided tools were useful", "I enjoyed the Wasteberg activity"*, and again *"What is Sustainable Development?"*. All the data collected from pre- and post-activity questionnaires were analyzed from both a qualitative and quantitative point of view.

Each step of the activity was also carried out with Cooperative learning. Cooperative learning is a student-centered, instructor-facilitated instructional strategy in which a small group of students is responsible for its own learning and the learning of all group members. Students interact with each other in the same group to acquire and practice the elements of a subject matter in order to solve a problem, complete a task or achieve a goal. Human learning is improved by the roles of culture and society, and language; interaction among peers is a magnifier of the learning processes (Slavin, 2011). During this phase of the activity each pupil had his own role. The Leader started the group off, made sure everyone understood the activity, encourage the group to focus on the topic and checked that everyone respected the proper role. The Writer wrote down the most important information about the task and wrote the ideas for the Speaker to present during the next phase. The Time Keeper was responsible of the time remaining to carry out the activity, reminding the group when half time was used and when time was nearly up. The Time Keeper also weighted the wasted and did the math calculations. The Speaker gave a feedback on the groups' work to the rest of the class.

THE WASTEBERG ACTIVITY

The activity was proposed after the preliminary questionnaire, starting with the engage phase during which the attention of the students was captured by the observation of a bag full of household waste. Different types of waste from packaging (glass, plastic, aluminum and paper) were collected and brought to the class. The students observed the waste and divided them by type. The pupils' attention was then focused on the following issues: a) how many different packaging were in the bag, b) which materials were composed of, c) from which raw materials they were made of, d) which georesources were exploited to make them, e) what is the energy required for the production of one kg of each type of waste determined before. Pupils were divided into 4 groups, one for each kind of waste. Then the actual Wasteberg was introduced to the students, represented as an iceberg-shaped cardboard panel divided in two parts: the upper part, smaller, resembled the part of ice of the iceberg over the water surface, whereas the lower part, larger, was covered and at the beginning not made visible to the students. To the upper part, the tip of the Wasteberg, some examples of waste were glued, whereas the lower part was, at the beginning, empty. The students were engaged therefore by the idea of determining what can fill the lower larger area. During the activity, the lower part was progressively filled up with symbols of what is produced, emitted or consumed (such as water, CO_2, resources, soil etc.) to produce the waste glued in the upper part of the Wasteberg (Fig. 1).

The IBSE question, which the pupils were then supposed to answer, was then introduced: *"How much waste do I produce when I throw away 1 kg of waste?"* The question seems tricky but it actually attracts the interest of the students, forcing them to think about resources consumption in the whole life-cycle of an item from production to landfill (from cradle to grave). To answer the question each group weighted its own waste and then calculated how much CO_2, chosen as a reference parameter for simplicity among several indicators, was emitted for the production of that amount of packaging. Then this value was compared to how much CO_2 can be instead saved by recycling it. This calculation was made for each type of waste, making use of an operational sheet (Fig. 2) which requires mathematical knowledge relative to the students' age group, such as ratios, proportions and percentage calculations, allowing a practical application of the mathematical concepts.

Each group then shared results and conclusions with the other groups. At the end they rank which kind of packaging is more environmentally friendly and the concept of the 4Rs (Reduce-Repair-Reuse-Recycle) was introduced (Montanari, 2009). The sharing time allowed interesting and interdisciplinary connections which emerged among pupils and between pupils and teachers, such as: *"Can we reduce the production of waste? How?", "How have geomaterials been used through history?", "Who did/do work in mines? How has the work of miners changed?", "What is the role of advertisement in consuming georesources?"*.

DATA ANALYSIS

The data collected in the experimentation were examined through a qualitative and a quantitative analysis (Acqua, 2018). The quantitative analysis has been used to elaborate the self-assessment results. The

Fig. 1 - Then Wasteberg represented as an iceberg-shaped cardboard panel divided in two parts.

qualitative data were elaborated with the aid of specific rubrics prepared in collaboration with the Department of Didàctica de la Matemàtica i les Ciències Experimentals at the Universitat Autonoma de Barcelona. Evaluation rubrics involved four levels, according to completeness, pertinence and correctness criteria of students' answers (Prat et al., 2000). The levels were defined as: Elaborated, Intermediate, Essential and Missing.

RESULTS

The data emerged from the evaluation of the forms completed by the students (questionnaires and during the Wasteberg activity) were analyzed, to gain information on the validity and effectiveness of the project.

QUANTITATIVE RESULTS

The class was composed of 63% males and 37% females with a total of 17 students. Focusing on results broken down by gender of the open-ended questionnaire, females demonstrated a performance better than males both before and after the activity regarding the *Missing* level (before: 47% males and 35% females, after: 21% males and 8% females) and *Essential* level (before: 42% males and 57% females, after: 42% males and 40% females). With regard to *Intermediate* level females had the same performance as males before activity (11% males and 8% females) but they improved the most after the activity (31% males and 48% females). In the *Elaborated* level females had the same performance as males before and after the activity but both improved after the activity, shifting from 0% to 5%. Generally speaking, after the activity there was a shift towards the upper levels of performance for both genders.

Regarding the self-assessment and reflection questionnaire, the data showed that the work carried out during the activity was satisfactory almost for the total of the pupils (94%), and 97% of them declared, although with different level of agreement, that they learned new concepts.

Operational Sheet

1. Compile the following chart related to your material using the chart 1:

KIND OF WASTE	WASTE WEIGHT	EMITTED CO_2 FOR *EX NOVO* PRODUCTION	EMITTED CO_2 WITH RECYCLING	SAVED CO_2 WITH RECYCLING

CHART 1

DATA FOR 1KG OF:	EMITTED CO_2 FOR *EX NOVO* PRODUCTION	EMITTED CO_2 WITH RECYCLING	SAVED CO_2 WITH RECYCLING
ALLUMINIUM	12,5 KG	0,6 KG	
GLASS	1 KG	0,8 KG	
PAPER	2,4 KG	1,1 KG	
PLASTIC	2,9 KG	2,03 KG	

2. Pay attention to the chart above and answer to the questions

Which is most convenient packaging if you consider emitted CO2 in the *ex novo* production?

____

Which is most convenient packaging if you consider emitted CO2 in the recycling process?

____

3. Put in order of importance the three following actions: TO RECYCLE, TO REUSE, TO REDUCE, TO REPAIR

____

Fig. 2 - Each group weighting its own waste and operational sheet

QUALITATIVE RESULTS

Sustainable Development is based on three pillars, which concern social, environmental and economic challenges. Therefore, topics from all these pillars were proposed in the activity and assessed by the questionnaires. In the questionnaire proposed before the activity there were many *Missing* answers and no answers at the *Elaborated* level. The very high amount of *Missing* level answers before the activity (41%) testifies the very little diffusion of the three pillars of the concepts of Sustainable Development in schools (Fig. 3a) suggesting also that the topics are not addressed in the family environment and therefore the students are not exposed to them. As expected, in the questionnaire proposed after the activity there was an improvement in the answers' correctness and in the general quality of the answers given, as shown in Figure 3a. The answers referring to the M*issing* level of performance decreased (29%) and there was an overall shift towards the upper levels. As an example, one *Elaborated* level answer and an *Essential* one, respectively, are reported here: *"Lo Sviluppo Sostenibile è l'insieme delle azioni che costituiscono la nostra vita quotidiana ma che non sono nocive per il futuro e per l'ambiente anzi tendono anche a migliorarlo. Quindi lo sviluppo delle industrie, del pianeta e delle persone che ci abitano, che si possono sviluppare e sostenere"* and *"Lo Sviluppo Sostenibile è quando tu butti via tipo una bottiglia nella plastica anziché nell'umido e così quella cosa viene riciclata e si può usare quella invece di sprecare altre risorse ed inquinare"*.

The number of the pupils switching from a lower level of performance to an upper one increased after the Wasteberg activity. Figure 3.b shows also the evolution of the concept of waste among the students: after the activity more pupils agree with the statement *"Waste is a resource"*, with an evident shift towards the answer "strongly agree". This means that the activity was successful in changing their previous ideas about waste.

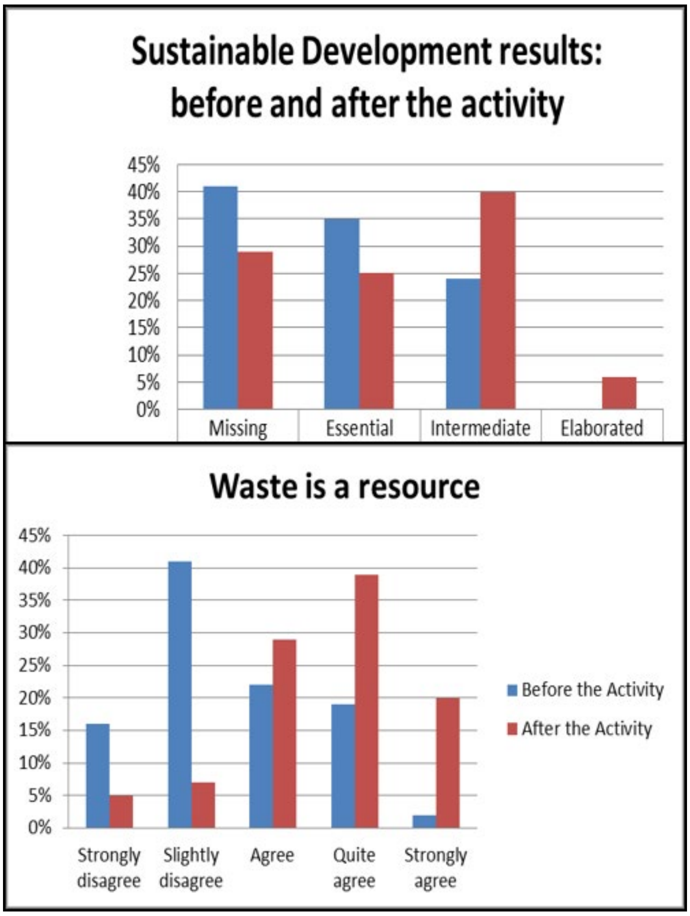

Fig. 3. - a: Answers comparison about Sustainable Development before and after the activity. b: The evolution of the concept of waste among the students before and after the activity

DISCUSSIONS

Some points of interest were observed during the experimentation in the classroom and others were evidenced thanks to the data evaluation.

The experimentation of the didactic activity allowed pupils to observe, measure, collect and interpret data, starting from a practical situation on a real topic. The IBSE approach positively influenced the students' engagement in the proposed topics and it was therefore determinant for the success of the activity. The students demonstrated a high level of concentration, but also an emotional involvement, possibly caused by the relationships of the topics with reality, which positively reflected on the acquisition of competences and involvement in the activity. The hands-on asset and the use of Wasteberg made pupils protagonists of their own learning, since they were involved through several perceptual channels (Head, Hearth and Hands; Pennesi, 2017). The individual improvement in the definition of Sustainable Development, detected thanks to the questionnaires, was obtained also thanks to the exchange of experiences and peer-tutoring during the team-working In fact, as early as 1992, Tomasello affirmed that *"The development of communicative competence as a whole, including not only lexical and syntactic skills but also various pragmatic skills, depends largely on feedback about communicative efficacy that children receive from different interactants. This feedback is used by children to make further inferences about the conventional functional significance of particular linguistic expressions. This social-pragmatic view of language acquisition obviates the need for a priori, specifically linguistic, format constraints on the language acquisition* process."

During the activity pupils were able to detected immediately water and CO_2 as hidden resources consumed behind the process of packaging production. The teacher's interventions was instead necessary in order to guide pupils' reasoning towards soil consumption, mining exploitation and wars for control over the resources, as other indicators that could be taken into consideration too for production of any object.

Before the activity the majority of pupils looked at waste only as something to eliminate from everyday life. After the activity there was a mental change: most pupils realized that packaging is composed of valuable resources and suddenly realized that waste might be a resource too. The activity allowed also to reflect on the fact that landfilling is a waste of resources, especially in Italy being a country poor in raw materials, and that landfilling is also an environmental risk. This complex mental change occurred in the little time of the activity and using a huge amount of interdisciplinary information, especially thinking about the young age of the students involved. However, the attention of the rapid change in opinions was probably the result of the cognitive conflict involving a discrepancy between previous cognitive structures (waste is definitively a waste) and new experience (waste is a resource). This confirm that knowledge proceeds neither from experience with external objects nor from intuitive or logical internal processes, but that it develops from a series of cognitive structures, built one above the other, requiring continuous adjustment and leading to further constructions (Piaget, 1977).

The use of Geosciences topics allowed to follow the whole process of production of an object, with its many interdisciplinary connections, introducing the students to topics which are not commonly proposed in school, like also to the concept of circular economy. It is evident that it would be important to create new didactic projects based with this approach, aimed at contributing to the teaching of Environmental Education but also at improving the dissemination of Geoscience at school.

The use of a topic related to the georesources allowed also to address complex and multidisciplinary concepts, which could be expanded to other actual issues, like the environmental problems connected to the landfilling, the soil consumption, the WEEE (Waste of Electric and Electronic Equipment) or the critical elements. They are suitable to be easily introduced in a follow up of the activity to include a more comprehensive approach, which however would require a longer time and a scaling of the activity for older students.

In the Middle school this activity positively involved teachers of different subjects in a class project which was used as a source of discussion during the scholastic year, with strong effects on long-term retainment of contents and knowledge. For example, the history teacher addressed immigration issues connecting them with availability of resources and their exploitation, strengthening the concepts emerged during the Wasteberg activity. The activity was also effective in making the pupils aware of the human role on the planet, recognizing that Earth's resources are limited and that their unequal access and distribution are a global issue. Furthermore, even if at the beginning, the focus is on direct waste, the materials that we interact with daily, they are just the tip of the wasteberg and once pupils visualize this concept can understand the waste issue from a new and groundbreaking perspective. Thanks to this acquired knowledge pupils could be more prone to possibly adopt an environmentally responsible lifestyle, as well as being able to transfer their attitude to other members of their family.

As a direct consequence of the involvement of the students in these themes, despite students are usually not aware of the relationship between their lifestyle and their impact on the environment, this activity involved them as active change-makers and as promoters of a new environmentally-friendly culture. In fact, the pupils realized a word cloud with key words emerged from their reflections: the more frequently a word is found, the larger it becomes in the word cloud. By looking at the words most reported by the pupils (Fig. 4) it is evident that new concepts enriched their knowledge, which was the purpose of the activity, and a new awareness arose among them.

As a final remark, the good atmosphere in which the experimentation took place and the positive acceptance by all the involved teachers, is an indication that these activities will be accepted with favor again in the future and also possibly reproduced by the same teachers, becoming therefore a first step of a change.

Fig. 4 - Word cloud made by pupils (translated by the authors)

TEACHER EVALUATION AND FUTURE IMPLICATIONS

The Wasteberg activity was structured based to the age of pupils (14-year-old) but can be easily re-calibrated for older students (upper secondary school): as hints for a future project, chemistry teachers could plan the analysis of waste samples or the detection of waste-pollutants in water, air and soil samples. Students can be encouraged by their economy teacher to elaborate integrated plans for development to be discussed in the class or proposed as an activity involving the school. Geography teachers and students could re-write the world map not following national boundaries but monitoring the trail of waste re-allocation. Italian or English literature teachers can address exploitation and child labour issues through classical authors: Verga with the short story "Ciaula scopre la luna" or Dickens with "Oliver Twist" making comparisons with child labour in modern developing countries. Art and Technology teachers, starting from actual productive processes, can investigate how to improve packaging in an ecofriendly view. Pupils can weight the waste using different kinds of balances (analogical, digital, a steelyard) and math teacher can address the topic of accuracy and sensitivity of measuring tool and of measurement errors.

For example, in the frame of the project the teachers involved in the experimentation realize a simple but interesting follow-up about a practical application of circular economy: pupils realized little objects, as key rings, necklaces, earrings and aprons using respectively corks, coffee pads and old jeans. These items were sold in a school fair, strengthening the concepts that almost everything can be recovered and reused, that waste can be turned into a resource and, if sold, there is a gain for all the people involved, not only for the environment.

The teachers, both those who have joined the experimentation with their school and those involved in the workshops during "Earth Week 2017" and the "Geoscience Summer School 2017" appreciated the activity for several reasons. As reported in the evaluation forms, they evidenced that the topics of the Environmental Educations were approached differently and more effectively compared to the usual traditional teaching; the topics of the agenda were proposed in an interdisciplinary way allowing links and new perspectives; they were able to learn and/or refine their knowledge about the IBSE approach via practical examples. Finally, what mostly impressed the teachers, in addition to the new approach, was that the activity proposed during the workshop, was easily reproducible, ready-to-use and the materials were directly made available for using in their classes.

CONCLUSIONS

The use of the Wasteberg activity and the topic of non-renewable resources, wrongly considered as infinitely available, allowed pupils to approach the topic by dealing with it using practical problems of everyday life. This allowed the development of a reticular and global thought (L'Ecuyer, 2012). In fact, generally people reject an imposed change, on the contrary they gladly accept it if they participate in it. The innovation is more successful if conceived as useful and easily viable through simple and good practices of daily life, such as to improve separated collection of waste and to reduce the consumption of not renewable resources (Sterlig, 2014). In fact, even the smallest change can be a step towards mental changes: think globally and act locally. According to us, this activity favored a deep engage in the assignment because pupils felt personally involved and acquired new competences starting from their basic knowledge. Also, connecting the study of geomaterials in the view of their use and recycle, was certainly successful from a didactic point of view.

The interdisciplinary approaches also supported this achievement and enhanced skills even in the pupils less prone to study. This approach can drive transition from *EGO* to *ECO* perspective; *EGO* means humankind rules over others, and the world can look like a really disregarded planet that was once beautiful. *ECO* means to be equal each other, respecting the others' differences and not to rule over others. As stated by Harari (2012): *"Our ancestors shared the planet with at least five other human species, and their role in the ecosystem was no greater than that of gorillas, fireflies, or jellyfish. Then, about 70,000 years ago, a mysterious change took place in the mind of Homo sapiens, transforming it into the master of the entire planet and the terror of the ecosystem. Today it stands on the verge of becoming a god, acquiring divine abilities of creation and destruction*." It is up to young generations to choose the path to be taken and it is the task of Education to form people in authentic freedom and consciousness.

Interesting insights can arise to deepen interdisciplinary connections such as the resources distribution in the world, the job exploitation, the immigration, the role of advertisement in consuming resources and so on. Geosciences become therefore a tool to study complex topics, connecting different skills and competences also from other disciplines.

The teaching of Environmental Education in the Italian schools allows very well approaching the concepts of Sustainable Development as suggested in EU Agenda 2030: *"Education transforms lives and is at the heart of UNESCO's mission to build peace, eradicate poverty and drive sustainable* development… *UNESCO provides global and regional leadership in education, strengthens education systems worldwide and responds to contemporary global challenges through education with gender equality an underlying principle…Its work encompasses educational development from pre-school to higher education and beyond. Themes include global citizenship and sustainable development, human rights and gender equality, health and HIV and AIDS, as well as technical and vocational skills development."*

The results of this experimentation proved that the concept of Sustainable Development (Agenda 2030) is still scarcely known both at school and in the family environment, but also demonstrated that even a simple didactic activity such as the Wasteberg is effective in attracting the interest of the students, increasing their environmental awareness, and helping the teachers to discuss the concepts of the Agenda, offering also many didactic possibilities to introduce more Geosciences in the science teaching.

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4.2.2. The daily ecological rucksack activity

In this paragraph a paper, entitled "*Engaging didactic activities to disseminate sustainability topics among students, as agents of change for a more sustainable world*", shows results concerning "the daily ecological rucksack activity". The article briefly explains methods and approaches used to prepare the activity. All the ready-to-use materials created for this activity are reported in Annexes 1 and 2. Cooperative and active learning have been efficient tools to vehicle among students the awareness about the environmental impact of their everyday life actions and routine.

The paper was submitted in the 13th annual International Conference of Education, Research and Innovation (ICERI, 2020), as a virtual presentation.

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ENGAGING DIDACTIC ACTIVITIES TO DISSEMINATE SUSTAINABILITY TOPICS AMONG STUDENTS, AS AGENTS OF CHANGE FOR A MORE SUSTAINABLE WORLD

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Abstract

In the last years all countries have been called to face environmental, economic and social concerns in the view of the Agenda 2030 for Maintainable Development and its Goals. This plan of action is aimed to achieve globally peace, social equality and prosperity for people and the planet. The research focuses on building/testing new engaging didactic activities aimed to introduce sustainability topics and to increase environmental awareness among students for taking action towards the environmental protection. Education to sustainability goes beyond the simple transfer of knowledge and it focuses on multiple perspectives, through a holistic and practical approach. To this aim, the didactical activities proposed were carried out using approaches like learning by doing, cooperative learning and learning by playing that put students at the center of the educational process. These approaches are particularly important for introducing the concept of sustainability at school since children, by adopting eco-friendly behaviors and lifestyles, can also contribute to the transformation of society towards the Goals of Agenda 2030. The activities are addressed to 11-years-old students and focus on natural resources sustainable consumption and waste production. Pupils calculated water, carbon, ecological footprints and the ecological rucksack of everyday life simple actions ("*My daily ecological rucksack*" activity). They worked in groups discussing and thinking critically about how their lifestyles can affect Earth's health. Then, they discussed on how to reduce their ecological footprint, through a puzzle game called "*Reduce your footprint*". The multidisciplinary approach used allows to discuss about topics of history, geography, science, math and technology closely connected to the concept of sustainability. The data were collected though pre-activity and post-activity questionnaires in order to evaluate the sustainability awareness achieved. The class experimentation allowed to determine how pupils worked to observe, measure, collect and interpret data, starting from a practical situation on a real topic or a gaming context. Results show that students improved their awareness about sustainability topics and demonstrated a high level of concentration, but also a high emotional involvement, which positively reflected on the acquisition of new competences and attitudes towards more eco-friendly lifestyles.

Keywords: Agenda 2030, teaching sustainability, learning-by-doing, learning-by-playing

1 INTRODUCTION

Education for sustainability should represent the highest priority at all educational levels since environmental, economic and social problems can undermine the future of the Earth [1],[2]. The Agenda 2030 is an action plan to achieve globally Sustainable Development for fighting poverty, inequalities and all the environmental concerns. The 17 goals and 169 targets of the Agenda focus on a set of global priorities to achieve Sustainable Development in five P-instances: People, Planet, Peace, Prosperity and Partnerships [3]. From this scenario, Sustainable Development concerns economic, social and environmental issues. The strengths of the 17 Goals for Sustainable Development are universality and the entanglement: they concern countries all over the world and they rely on each other. Ending poverty must go hand-in-hand with strategies that build economic growth and address a range of social needs including education, health, equality and job opportunities while tackling climate change and working to preserve our ocean and forests. The SDGs are integrated, which means that they recognize that action in one area will affect outcomes in others, and that development must balance social, economic and environmental sustainability. Through the pledge to "Leave No One Behind" in the Agenda 2030, countries have committed to fast-track progress for those poorest.

The Goal 4 (quality education) aims to ensure inclusive and equitable quality education and promote lifelong learning opportunities for all. This Goal and its targets advance a model where learning, in all its ways, has the power to influence people choices and to create more inclusive and sustainable societies [4]. At school, teaching topics related to sustainability and the Agenda 2030Goals allow to ensure students' participation in a global transformation process, as agents of change towards sustainability. Increased educational attainment for sustainability is associated with increased environmental awareness, concern and, in some context, action, so students are more likely to get involved in political activities to protect the environment. Sustainable development touches several school disciplines such as geology, biology, history, geography and technology, so education for sustainability has to rely on interdisciplinary and multidisciplinary approaches, as it has been raised by several authors [5],[6],[7],[8]. Interdisciplinarity allows to break down the content area of the single course matters using a holistic approach, therefore, teachers should connect learning with real-life situations and with other disciplines [9]. This kind of education goes beyond the simple transfer of knowledge and focuses on multiple perspectives: economic, ecological, environmental and socio-cultural, which contribute to make students becoming empowered, critical, mindful and competent citizens.

Although a wide literature highlights the pedagogical importance of education for sustainability [10],[1],[11],[12], there is still a lack of well-tested didactic activities about this topic the teachers could use in the Middle Schools, in spite of the fact that some authors have carried out didactical experiences about sustainable development topics suitable for Higher Education [13],[14]. This research follows a series of experimentations in Geoscience education carried out in the frame of the PhD program at University of Camerino, Italy. The UNICAMearth research group, composed by geoscience researchers and teachers carrying out their PhD in geoscience education, focused to create and testing didactic activities addressed to 11-14 years old students [15],[16], [17],[18]. In fact, due to work overload and chronical lack of time, teachers have often trouble working in team with colleagues of different matters in order to produce interdisciplinary and laboratorial didactical paths.

This research contributes to building and testing at school new engaging and interdisciplinary didactic activities, aimed to address students to sustainability topics. The activities rely on multidisciplinary and interdisciplinary approaches because they link several matters (science, geography, technology, math) and encourage students to critical thinking about the holistic dimension of sustainability. Ready-to-use didactic materials have been created in order to give teachers all the tools necessary for working with pupils, using cheap materials. Since education for sustainability enables students for multiple challenges and can facilitate changes in values, world views and behavior, the didactic approaches used have to put students at the middle of the learning process, through a constructivist learning. In fact, in the following didactic activities experiential learning, learning by doing and learning by playing have been applied in order to improve students' motivation, interest and environmental awareness and eco-friendly lifestyles. The role of education, in fact, is to integrate pupils' global responsibility into their visions, goals and practices [3].

The authors created a series of didactic activities inside a didactic pathway about sustainability and ecological footprint issues. In this paper the focus is on activities for 11-years-old- students. The aim of this research is to make pupils aware that goods production requires the utilization of a large amount of natural resources. According to Goal 12 for Sustainable Development (responsible consumption and production), consumption habits imply responsibility. Therefore, a progressive awareness of materials and energy useful to produce goods and services on a daily basis and knowledge of the implication of consumption choices are prerequisites for steps sustainable behavior. The exploitation, use and sustainable consumption of georesources offer ample possibilities to approach many modern and actual subjects and issues, which can involve the students' everyday life with an attention to the territory they live in [17]. Finally, the didactic activities were planned to verify if a Geoscience-related activity could improve the interest in Geoscience and Agenda 2030 topics, and could also indirectly contribute in improving the scientific and mathematic competences of the pupils, by using practical applications.

2 METHODOLOGY

The experimentation of the activities was carried out in two classes of 11-years-old-students. The activity topic is the ecological footprint of everyday life actions, which is divided in two parts, the first is called "*My daily ecological rucksack*" and is divided in 2 lessons and 7 phases, as described in Tab. 1 and Fig.1, where the main features are reported. The second part is called "*Reduce your footprint*" and is a team challenge.

Table 1. Description of the didactic activities.

Topic	Title	Duration	Didactical approaches	Description of the activity
The ecological footprint of everyday life actions	"*My daily ecological rucksack*"	3 h	Cooperative learning Learning by doing	Students are divided into groups and they have to calculate the water, carbon and soil footprint of their main everyday life actions (referred to one day)
	"*Reduce your footprint*"	20 min	Learning by playing	Team-challenge: the students compose a puzzle, joining the right ecological footprint to each main everyday life action, from the biggest to the smallest one.

At the beginning of the two activities pupils were given a questionnaire, composed both by a series of statements to rank with Likert scale and by open-answer questions about Sustainable Development and aware consumption, to evaluate their familiarity with these topics. A 5 levels Likert scale was used to rate the agreement/disagreement on specific items. The same questionnaire was administered at the end of the activities to evaluate the didactic outcomes.

2.1 "My daily ecological rucksack" activity

This activity has been carried out in order to make students become aware of the ecological footprint of their simple everyday life actions (e.g., washing, drinking water in plastic bottle, dressing). The activity steps are represented in Fig.1.

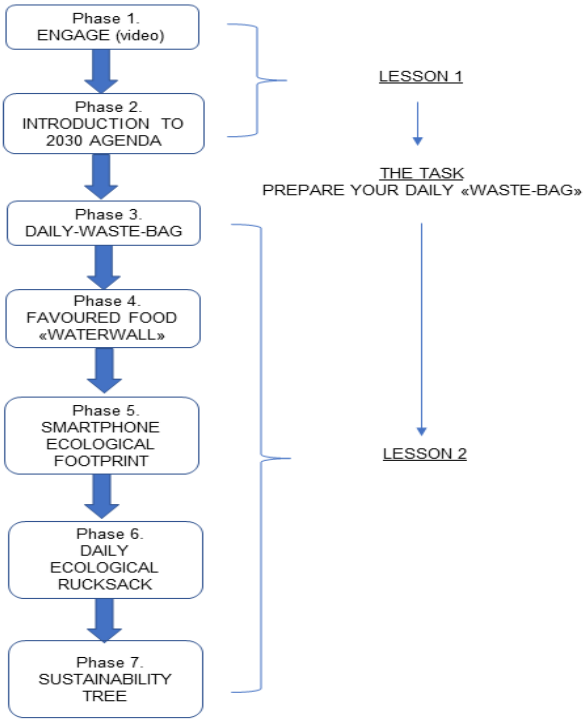

Figure 1. Ecological rucksack activity phases.

At the beginning of the first lesson, as an engage phase (phase 1), an emotionally involving video ("*The colour of your dream city*", https://www.youtube.com/watch?v=rASj9loN0rk) was shown. In this video a group of kids and their parents share their vision of the future of the world nowadays afflicted by serious environmental problems. Then, a brainstorming phase was carried out in order to discuss with students their vision of Earth environmental condition and social problems, future perspectives and possible solutions (phase 2). With the help of the history and geography teachers, social issues like global poverty and inequalities were discussed.

A brief introduction to the Sustainable Development, Agenda 2030 and ecological footprint topics followed, using an interdisciplinary approach and a video about Malala Yousafzai making appeal to young people and presenting the Agenda 2030 (https://www.youtube.com/watch?v=T__s__oDGOQ&t=204s). Previously, the teacher of Italian had already approached students to the story of Malala, her fights against inequalities and her speeches to the ONU Assembly. Therefore, students appreciated the video because of their familiarity with this character and Malala's young age.

The discussion about products ecological footprint raised the pupils' previous knowledges about the production process of some materials, like paper, plastic, aluminium and glass they had studied with technology teacher. Then, the researcher gave students a task to carry out in preparation of the following meeting: the preparation of a personal "daily waste-bag". The "waste-bag" was a simple bag filled up with objects as symbols of daily consumption and waste production: pieces of products' packaging, plastic bottles and sheets of coloured paper (green for organic waste) and blue (for water consumed). In these sheets students had to write notes about food thrown away in the garbage and all the daily actions that required water consumption.

In the second lesson (phase 3), students were divided into groups of 3 components with specific tasks (the leader, the mathematician and the environmentalist). Each group discussed about the daily "waste-bag" of both their natural resources consumption (e.g. water for drinking and washing) and waste production (packaging, food leftover, objects and products packaging thrown into the trash). In this phase, the idea of how many types of waste are produced in a day began to spread among pupils.

In order to introduce the concept of the ecological footprint of a product, each group calculated the water footprint of a favoured food (phase 4) and the water, carbon and ecological footprint of their smartphones (phase 5). In phases 4 and 5, the researcher gave students some reference data tables and operational sheets with some boxes to be coloured, on the basis of the footprint numerical values (with a specific measurement unit). The "waterwall", for example, is a table with a lot of rows and columns, composed by boxes, where each box represents one litre of water. In the phase 6, groups calculated the water, carbon and soil footprint of their daily actions (washing, dressing, drinking water in plastic bottle, eating, using smartphones and computer…) with the help of reference data tables and the operational sheets prepared.

In Table 2, a description of students' ecological rucksack composition is reported (phase 6). At the end, each group calculated the weight of own daily ecological rucksack, considering the total carbon, water and ecological footprint of all the actions. The ratio between the weight of groups' ecological rucksack and the weight of a reference sample was calculated. The reference sample is a simple rucksack filled up with a bottle of water (1 litre), a package of soil (1 Kg) and a package of cement (1Kg) to simulate CO_2 emission in the atmosphere. This practical approach allowed them to verify directly how much humans' actions make the ecological rucksack "heavy" in terms of environmental impact.

Table 2. Students' ecological rucksack.

Composition of the ecological rucksack	
Daily actions	Teamwork activity
1. Drinking water from a plastic bottle	Computation of water, soil and carbon footprint (considering also the transport) of water plastic bottles consumed in a day
2. Eating	Computation of water, carbon and soil footprint of foods' packaging thrown away Computation of water, carbon and soil footprint of food waste
3. Dressing	Computation of water, carbon and soil footprint of clothes the students wear that day
4. Washing	Computation of number of daily showers or baths, hands washing and tooth brushes. Computation of water consumption related to all these actions and how they are done (e.g., minding to close the water tap or not) Computation of water, carbon and soil footprint of plastic bottles containing washing products, thrown away in the garbage
5. Studying	Computation of water, carbon and soil footprint of sheets of paper consumed
6. Using smartphone and computer	Computation of water, carbon and soil footprint of smartphone production and of surfing the web

In phase 7 students were invited to compose the "Sustainability tree", as an authentic assignment to carry out in the following days. Pupils, in fact, were encouraged to take action towards sustainability in their everyday life, documenting their eco-friendly behaviors with photos. The "Sustainability tree" is a cardboard poster in the shape of a tree, where students could attach their photos of simple sustainable actions they carried out (fig.2). The tree symbolizes the hope of a transformation process that could be realized first by young people. The teachers of the different courses were invited to cooperate with students in order to reach this task and discuss the value of their changes of mind, to encourage them to become also agents of change in their class, family, environment.

Fig.2 The "Sustainability tree".

2.2 "*Reduce your footprint*"

The last part of the experimentation was carried out using a puzzle-game and a team challenge. The teams of 4-5 players were asked to join the pieces of a puzzle representing everyday life actions with the corresponding ecological footprint picture, from the biggest to the smallest one. The daily actions represented were divided into five categories: washing, using smartphones, dressing, eating, shopping in a supermarket. For example, in the case of "shopping in a supermarket", the biggest footprint action is to buy only packed goods from foreign countries. On the contrary, the choice of choosing unpacked and local products is represented by the smallest footprint action. Between these two extreme actions, others were to be placed in intermediate positions. Teams objective was to compose their own part of the puzzle correctly, to reach the goal piece called "*Reduce your footprint*". The winner team was the faster one (Fig.3).

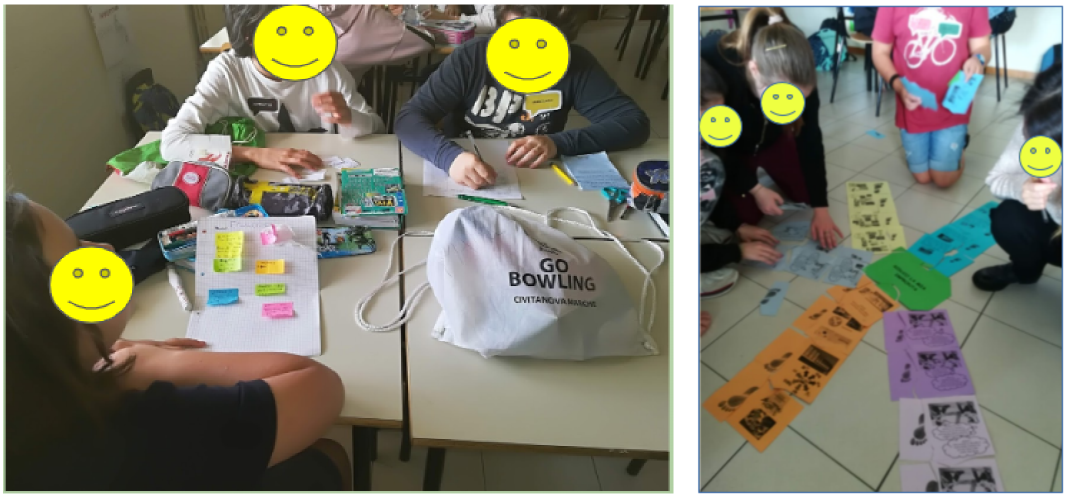

Figure 3. Students working on the activities related to "my daily ecological rucksack" (left) and "reduce your footprint" (right

2 RESULTS

The data emerged from the evaluation of the forms completed by the students (pre- and post- activity questionnaires) were analyzed, to gain information on the validity and effectiveness of this educational activity about sustainability. Results show a general improvement in pupils' awareness about sustainability, for example in their opinion towards goods consumption or circular economy, for example asking them if it was important to buying often new products (Fig. 4). In fact, pupils discovered that behind the production of goods there is consumption of a large amount of natural resources, like water, soil and minerals, as well as CO_2 production/emission. During the activity they became familiar with terms like water, carbon, soil footprint and environmental impact, applied to everyday activities and objects familiar to them.

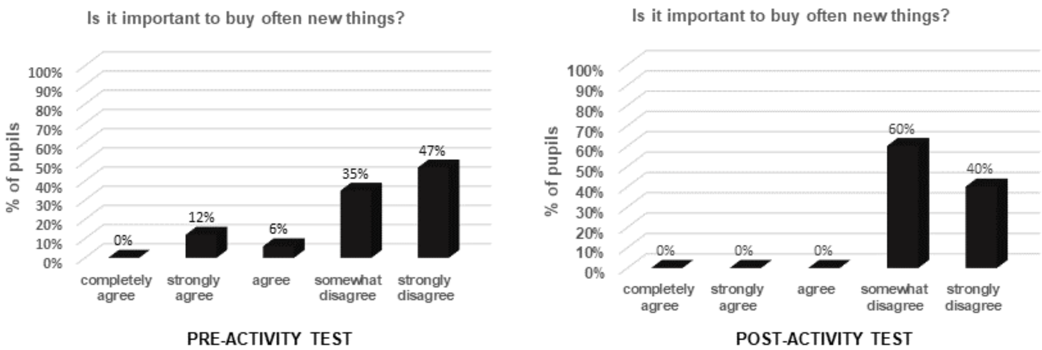

Figure 4. Pupils' opinions about the importance of buying often new things.

Pupils also learned what is a resource and what is the difference between renewable and non-renewable resources. In spite of being aware of the importance of water and minerals, they also increased their knowledge on the role of soil as a resource and that waste (for example organic waste or broken objects) could become a resource as well (Fig. 5). Moreover, waste could become important resources by different processes, like reusing, repairing and recycling. Therefore, students became more mindful that consumerism has a significant impact on the environment and that consumption is a key issue of a more Sustainable Development, according to Goal 12 of 2030 Agenda. The Goal 12 (aware consumption and production) stresses both sustainable management and efficient use of natural resources and reduction of waste generation through prevention, reduction, recycling and reusing.

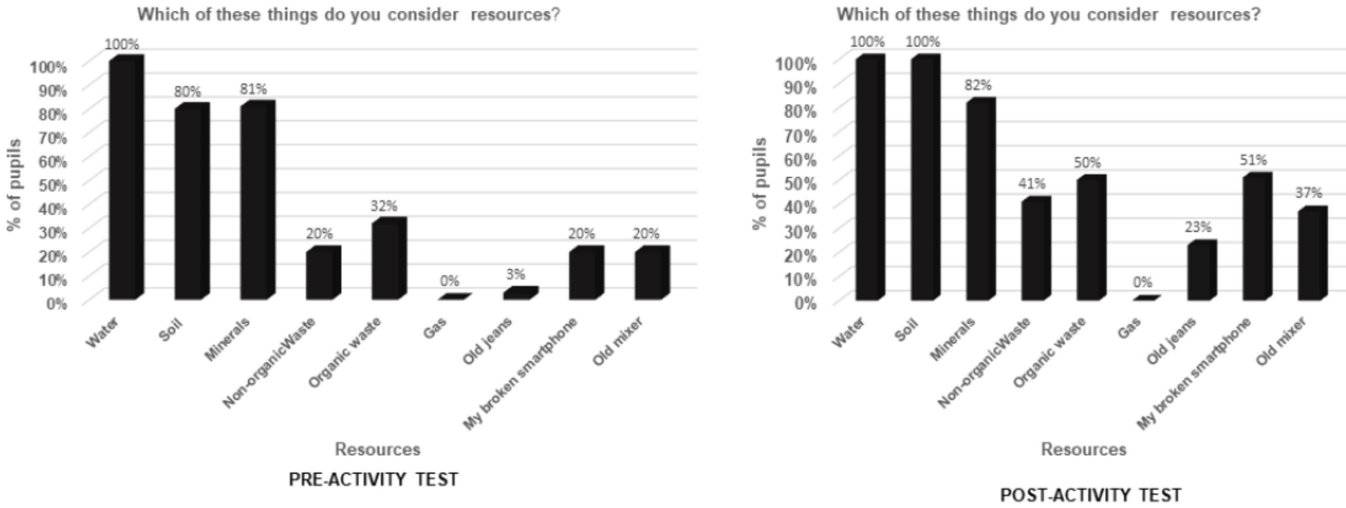

Figure 5. Pupils' opinions about what could be considered a resource.

The videos chosen as the engaging part of the activity were effective to introduce multidisciplinary discussions with the participation of other class teachers. In this way, the activity was shared and the students received inputs to build up a deeper and wider awareness of the reasons to pursue the Agenda 2030 goals and the consequences of a lack of environmentally-friendly behaviours.

Furthermore, "*My daily ecological rucksack*" activity required pupils to apply mathematician computation capabilities and problem-solving competencies. The students realized also that all the disciplines in school are related to each other and can help explain the evolution of the human history. They also realized that human actions can put at risk the environment or even life on Earth. The "Sustainability tree" testify the raising eco-friendly awareness of the students' lifestyles documented in a day and acquired thanks to the learning experience and discussion at school. Main actions represented in the tree were waste recycling, both plastic and food waste, saving of water consumption. Finally, during all the activities, the students worked showing enthusiasm, attention, motivation and a high emotional involvement.

3 CONCLUSIONS

Education for sustainability aims to help learners develop the necessary knowledge, understanding, skills, values, capabilities and dispositions to respond to the complex socio-ecological issues of the 21st century. Education must be future-oriented, focusing on protecting the environment and creating a more ecologically safe and socially fair world, through informed action. Other characteristics include inter/transdisciplinary—holistic thinking, transformation, divergent thinking, and having a proactive attitude.

In this research the interdisciplinary approach allowed to give students an integrative vision of sustainability. Education for sustainability should focus on changing consumption habits among students to become action makers in a society more environmentally aware and friendly. According to the Agenda 2030 Goal 12, people consumption needs to be reduced in developed countries and waste disposal needs to decrease/stop. As claimed by Lozano and Young [19], the way to assess changes on students' personal life inspired by "education to sustainability" programmes is still a challenge. Nevertheless, the results of this study show that pupils, with a simple activity, have rapidly improved their awareness about the large amount of georesources needed to produce common goods and about the possibility to save them by reusing, repairing and recycling objects.

Didactic approaches as learning by doing, cooperative learning and learning by playing are useful in education for sustainability since put students in the middle of the educational process. Children can contribute to the transformation process of society adopting eco-friendly behaviors and lifestyles, for example reducing waste and consuming less. This kind of active learning facilitates integrative, innovative, creative and critical thinking. Think critically enables students to become agents of change, working cooperatively to address the great challenges of this era and their future.

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4.3. Activity B- Responsible food consumption

This paragraph is devoted to the results of Activity B experimentation. They are presented in a paper, entitled **“***How much Earth is on my plate?” a special challenge-game to evaluate foods’ ecological footprint”*. All the ready-to-use materials realized for this activity are in Annexes 4, 5 and 6. Active learning and a team-challenge game were useful approaches to make students conscious that responsible food consumption is necessary for Earth’s health, because of the big ecological footprint of food production. The paper was presented at the 90° Conference of Italian Geological Society in September 2021. The numbering of all tables and figures follows that used in this PhD thesis.

“HOW MUCH EARTH IS ON MY PLATE?” A SPECIAL CHALLENGE-GAME TO EVALUATE FOOD ECOLOGICAL FOOTPRINT

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ABSTRACT

“How much Earth is on my plate?” is a didactic activity that aims to address students to the topic of foods’ water, carbon and ecological footprint and, in a broader view, to encourage them in taking action towards sustainable consumption. The activity has been created in the frame of the Agenda 2030, pointing out the urgent need of a social reorientation towards responsible consumption and production (Goal 12). “How much Earth is on my plate?” is a learning-by-doing and cooperative learning activity based on a team challenge game. The gaming-challenge approach allows students to engage and enjoy themselves, increasing their own awareness about Geoscience topics such as natural resources (water and soil) exploitation and the carbon footprint due to food production and consumption. The team challenge aims to organize a daily menu throughout the choice of five foods for each daily meal. The winner team is the one that collects the menu with the lowest ecological footprint. The activity was tested with 45 K7 students, but it is easily adaptable to younger or older students (K6-K8).

Students were invited to do a simulated grocery shopping and to work in teams using tools such as food pictures (including labels and packaging), posters, reference data and operational sheets. The team-work allowed students to evaluate, discuss and think critically about the water, carbon and ecological footprints of food and the environmental impact of their transport and packaging. Pre-activity and post-activity questionnaires were administered in order to evaluate students' awareness about use of soil, georesources exploitation and ecological footprint related to food production and consumption. Results are very satisfying in terms of involvement of students and show an improvement in pupils' consciousness on the tremendous environmental impact of food production and consumption, especially meat as well as imported products. The challenge engaged students in thinking critically about the environmental impact of their choices and how they could change behaviors in an eco-friendly manner. Pupils also discovered that a healthy diet for humans is healthy for our planet as well.

INTRODUCTION

The Agenda 2030 for Sustainable Development (UN, 2015) is a plan of action that aims to promote global peace and achieve the Sustainable Development already defined by the Brundtland Report (WECD,1987). The UN member states declared to be determined to foster peaceful and just ensuring inclusive societies free from violence and fear, thanks to a more sustainable world. The main goals are to achieve global peace and to fight poverty and hunger. This challenge requires the planet's protection from degradation, including sustainable consumption and production (Sustainable Developments Goal, SDG12), sustainably managing natural resources (SDG6) and taking urgent action on climate change (SDG13) in order to support the needs of present and future generations. SDG 12 suggests the right way towards an overcoming of consumerism. People, starting from the young and students, have to be educated on the ecological footprint of daily-use goods, everyday life actions and food consumption. They could become aware about the big amount of natural resources and carbon emissions behind daily-routine actions and consumption.

The production and consumption of food is one of the major determinants of environmental degradation at the global scale (Cucurachi et al., 2019). Likewise, individual dietary choices show an ever-growing demand for highly processed foods, refined sugars and fats, oils, and meats, determining serious impacts on human health.

The global food system accounts for 17–30% of anthropogenic greenhouse gas (GHG) emissions (Osei-Owusu, A.K. et al., 2021; Crippa et al., 2021; Vermeulen et al., 2012), 70% of freshwater use (Mekonnen and Hoekstra, 2014) and 38% of the earth's ice-free land area (Foley et al., 2005). In particular, livestock is responsible for more than half of the global food systems' GHG emissions (Gerber et al., 2013) and a third of agricultural land and water use (Hoekstra, 2014; Steinfeld et al., 2010). The supply chains of the food industry involve processing, production, and transport, which continues to grow in parallel to the rising world population (Kucukvar et al., 2016). Life cycle assessment (LCA) models are used to measure environmental impacts of food products (such as dairy products, fresh food categories, and beverages) from cradle-to-grave involving raw materials acquisition and processing, production, packaging, distributing, and end-of-life (Kucukvar and Samadi, 2015; Tasca et al., 2017).

A meta-analysis of life-cycle assessment (LCA) of food systems studies suggests that 100 g of protein of beef from a beef herd (not a dairy herd) determine an average impact score for climate change of 50 kg CO_2-equivalents, while determining a land use of 164 m^2 per year. On the other hand, the climate-change and land-use impacts of the protein-equivalent for peas, are over 100-fold and almost 50-fold lower than those of beef. Global LCA studies suggest that the cultivation of irrigated wheat, rice, maize, and sugar cane are global drivers of water scarcity and land stress. In terms of GHG emissions, wheat has one-fifth of the carbon footprint per gram of protein in rice (Cucurachi, 2019).

Given the planet's finite resources, a growing body of literature emphasizes the broken and unsustainable state of the current global food system (Harwatt, 2019; Rosenzweig et al., 2020). The global production of meat and dairy is expected to increase by 73% and 58%, respectively, in 2050 compared to 2011 (McLeod, 2011; Tilman and Clark, 2014). Moreover, research has shown that the increasing demand for animal-sourced foods also presents a daunting challenge of meeting global climate and environmental targets (Crippa et al., 2021; Herrero et al., 2015; IPCC, 2019). Therefore, there is an urgent need for science-based monitoring, controlling, and mitigating the environmental impacts of the global food systems for effective climate change mitigation, natural resource and biodiversity conservation (Galli et al., 2015; Smith et al., 2013).

There is also an urgent need to stimulate more conscious dietary changes that can potentially reduce environmental impacts more than technological solutions implemented at the production stages of the life cycle of foods. In particular, compared with the projected 2050 income-dependent diet, significant reductions in environmental impacts can be achieved by switching to a Mediterranean, pescatarian, and vegetarian diet, respectively. Transformative benefit would be achieved in relation to human health as well. Planetary health and human health are strictly interconnected and indivisible.

Education for Sustainable Development and sustainable lifestyles is stressed in the target 7 of SDG4: *"help people develop knowledge, skills, values and behaviours needed for sustainable development*" (UN, 2015). Therefore, teachers have the role to promote in pupils a culture of active players for social and environmental challenges. Moreover, the Agenda 2030 is one of the main key-topics of Citizenship education. In 2015 the Italian School National Department formalized a law for the integration of Citizenship Education in all School Curricula (MIUR, D.M. N.35 22 June, 2019). According to this new law, Citizenship Education could be addressed both as a distinct subject and as a matter spread in various disciplines. In both ways, interdisciplinarity should be the core of this issue.

"*How much Earth is on my plate*?" is a learning by-doing and by gaming didactic activity about the environmental impact of food production and consumption, thinking about the food lifecycle (raw materials, industrial production, packaging, transport and waste). This activity focuses on the water, carbon and ecological footprint of foods and aims to make pupils conscious that a diet richer in local vegetables and fruits, legumes and cereals than in meat (especially red meat) is healthy both for humans and for Earth.

The didactic approaches chosen are very useful tools to address sustainability topics. Since sustainability topics are complex, global and local, social and individual, constructivism is the instructional design theory of choice. Planting the seeds of Sustainability through education means learning by doing not learning by osmosis (Hedden, 2017). Using constructivism to teach sustainability de facto requires a hands-on approach whereby students learn by experiencing and interacting. By actively engaging in sustainability issues, pupils gain a deeper understanding of their complexity. Teaching students to become environmentally emancipated means preparing them for the real-world challenges of sustainability at all levels (local, national, and international). For this aim, a challenge game prompts them to develop their critical thinking in order to tackle current sustainability-related issues and, where necessary, challenge the status quo. Learning-by-gaming improves system thinking, engaging players in cognitive demanding tasks, requiring problem-solving and decision-making skills (Fabricatore, 2012). In fact, games support knowledge and skills learning through fun, in a situated and meaningful context.

MATERIALS AND METHODS

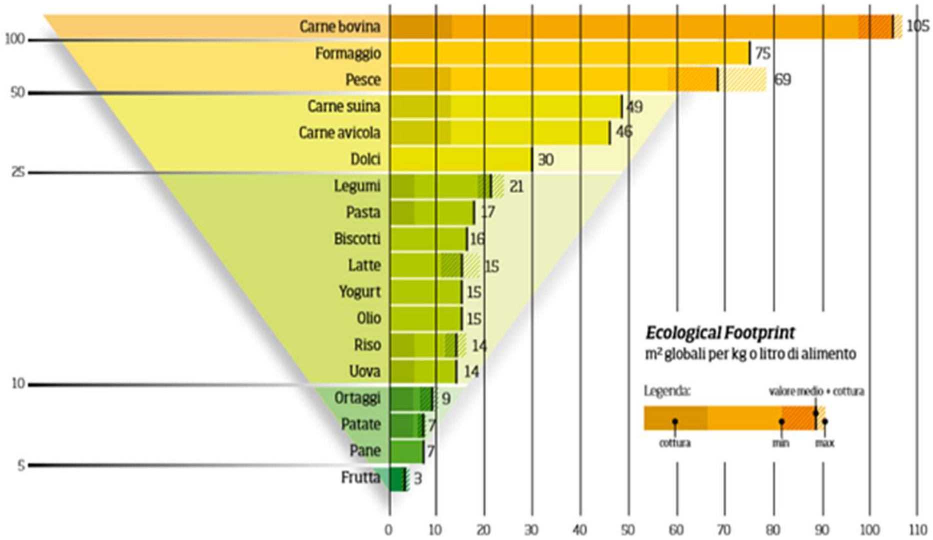
"*How much Earth is on my plate*?" is a learning-by-doing and cooperative learning activity about the ecological footprint of food. The activity is a team-challenge game achievable using raw materials and ready-to-use tools (sheets, boards, pictures, photos). The experimentation was carried out with 45 students but it is easily adaptable to younger or older students (K6-K8). The gaming-challenge approach allows students to engage and enjoy themselves, increasing their own awareness about Geoscience topics such as natural resources (water and soil) exploitation and the carbon footprint due to food production and consumption.

Each step of activity was carried out with cooperative learning too and pupils were divided into 4-player teams. During this phase each pupil had his own role. The Leader started the group off, made sure everyone understood the activity, encouraged the group to focus on the topic and checked that everyone respected the proper role. The Writer wrote down the most important information about the task and wrote the ideas of the team. The Time Keeper was responsible for the time remaining to carry out the activity, reminding the group when half time was used and when time was nearly up. The Time Keeper also did the math calculations. The Speaker gave feedback on the groups' work to the rest of the class.

Teams were invited to accomplish the task: "*Prepare the best daily menu".* The aim of the challenge is, in fact, to organize 4 daily meals (breakfast, lunch, break and dinner) in the best possible way, following the players' tastes and preferences. Each team had to do a simulated grocery shopping in a home-made market, choosing photos of five types of food for each meal and then putting them on the cardboard table (Fig. 4.1). The home made market is a collection of photos representing common food products that were selected and divided into categories: meat, fish, vegetables, fruits, cereals, legumes and cakes. The researcher chose, within each food category, different types of products (Italian/ foreign, local/ no local, Bio/no Bio, packaged/unpackaged…), in order to highlight their different environmental impact.

Fig.4.1. Pupils' work preparing the four daily meals.

Then, a team work followed: pupils had to calculate the water, carbon and ecological footprint of the chosen products, analyzing labels and packagings and using reference and operational sheets (Fig. 4.2). The reference data sheets report food pyramids of water, carbon and ecological footprint, calculated on the basis of food life-cycle. Moreover, students analyzed data about the ecological footprint and recyclability of eventual packaging from different materials (plastic, paper, glass and aluminum). The lecture of labels allowed pupils to observe: how to recycle the different parts of food packaging, the origin of products (NON EU/EU/Italian/local), the kind of food production (conventional or biological agriculture and intensive livestock farming or not intensively-exploited livestock).



FRUTTA							
	Descrizione	Impronta (idrica, del carbonio, ecologica) vedi piramidi alimentari in allegato	Punti impatto ambientale per tipo di alimento per impronta ecologica	Punti impatto ambientale per tipo di imballaggio	Punti impatto ambientale per tipo di imballaggio	Punti impatto ambientale per origine	Punti impatto ambientale per particolari certificazioni (bio, fairtarde…)
Pezzo 1							
Pezzo 2							
Pezzo 3							
Pezzo 4							

Fig.4.2. Examples of reference and operational sheets.

As in every challenge-game, players collect a score. In this case, a symbolic score was associated with each food product, in relationship with its environmental impact. The score, in fact, depends on the ecological footprint, origin, kind of packaging and quality of the product (biological, equo-solidale…). The higher the environmental impact, the higher the score is obtained. The teams had to calculate their own score using the sheets and then communicate to the others. As a surprise effect, students discovered that, unusually, the winning team is the one that collects the lowest score. A final discussion allowed groups to think critically about their consumption habits and choices, posing questions such as: "*Can we reduce the environmental impact of our food consumption? How*?", "*Can we sensibilize our family and our friends towards responsible food consumption*?", "*How can we change our shopping habits*?", "*How important is our individual lifestyle for Earth planet health*?".

At the beginning of the activity, pupils were given a questionnaire, composed both by a series of statements to rank with Likert scale and by open-answer questions about aware food consumption, to evaluate their familiarity with this topic. A 5 level Likert scale was used to rate the agreement/disagreement on specific items. The same questionnaire was administered at the end of the activities to evaluate the didactic outcomes.

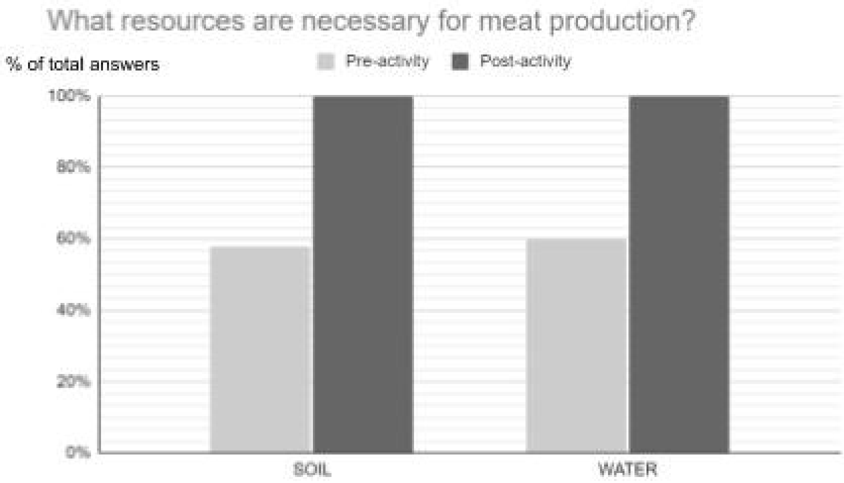
The data were elaborated with the aid of specific rubrics to obtain an analytic evaluation (Prat et al., 2000; Stacchiotti, 2019). Evaluation rubrics involved four levels, according to completeness, pertinence and correctness criteria of students' answers. The levels were defined as: Elaborated, Intermediate, Essential and Missing. Finally, teachers were given a satisfaction questionnaire in order to know their points of view and obtain useful suggestions.

RESULTS

The data emerged from the evaluation of the forms and completed by the students were analyzed, to gain information on the validity and effectiveness of the project.

QUANTITATIVE RESULTS

Focusing on results broken down by questionnaire of 5-Likert Scale statements, students demonstrated an improvement in awareness about the environmental impact of foods after the activity. With regard to the natural resources necessary for meat production (Fig.4.3), pupils' opinion that a big amount of water and soil is necessary increased (60% pre-activity; 100% post-activity). Furthermore, most pupils declared that locally-produced food (so called Km 0) consumption can drastically reduce carbon emissions as well as biological food that is safe for planet health too (95% and 97% respectively post-activity answers. Furthermore, responsible food consumption and diet becomes extremely important not only for human health but also for Earth planet safety (100% of the total answers, Fig.4.4).



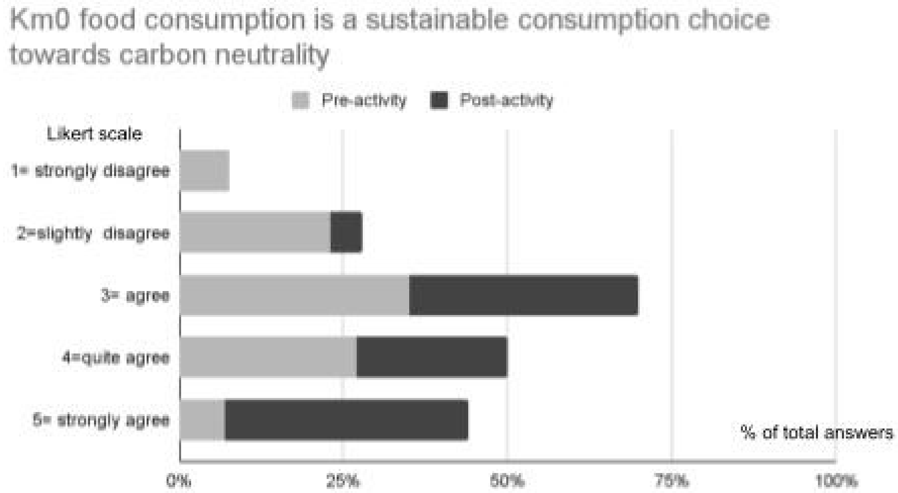


Fig. 4.3. Student's answers about the ecological footprint of meat and the importance of km0 food production.

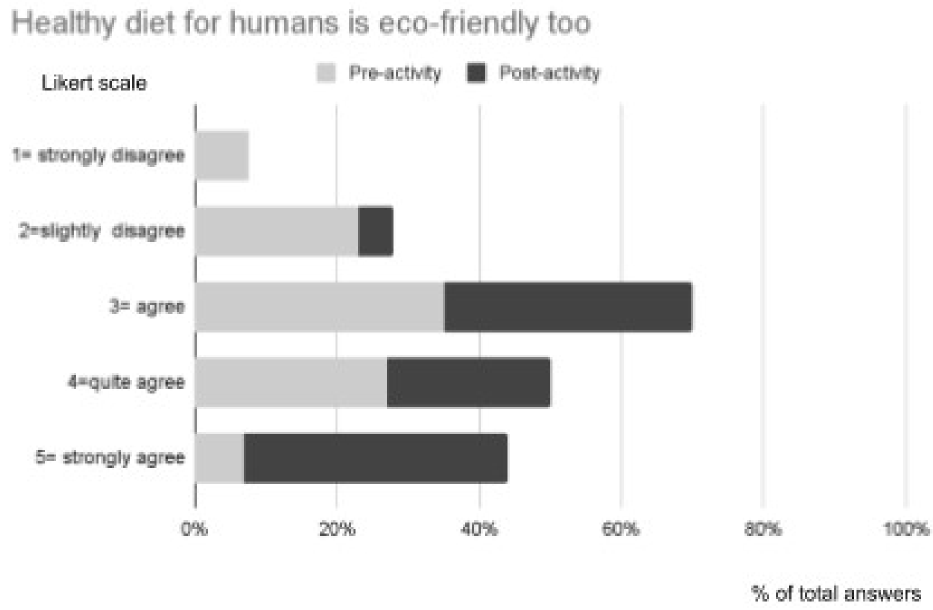


Fig.4.4. Students' answers about the importance of a healthy diet for the planet.

QUALITATIVE ANALYSIS

Responsible consumption is an interdisciplinary and multi-faced topic. In pupils' questionnaires they were asked to give a definition of responsible consumption, especially in relation to food consumption.

In the questionnaire proposed before the activity there were many Missing answers and no answers at the Elaborated level. The significant amount of Missing level answers before the activity (33%) testifies the very little diffusion of the environmental impact of food consumption topic, suggesting also that is not addressed in the family and social environment. As expected, in the questionnaire proposed after the activity there was an improvement in the answers' correctness and in the general quality of the answers given, as shown in Fig.4.5. The number of answers referring to the Missing level of performance decreased (17%) and there was an overall shift towards the upper levels. As an example, one Elaborated level answer and an Essential one, respectively, are reported here: "*consumare in modo consapevole significa utilizzare beni e servizi tenendo in considerazione le risorse utilizzate e l'inquinamento prodotto, quindi scegliere prodotti con basso impatto ambientale*", and "*sapere quello che si consuma*".

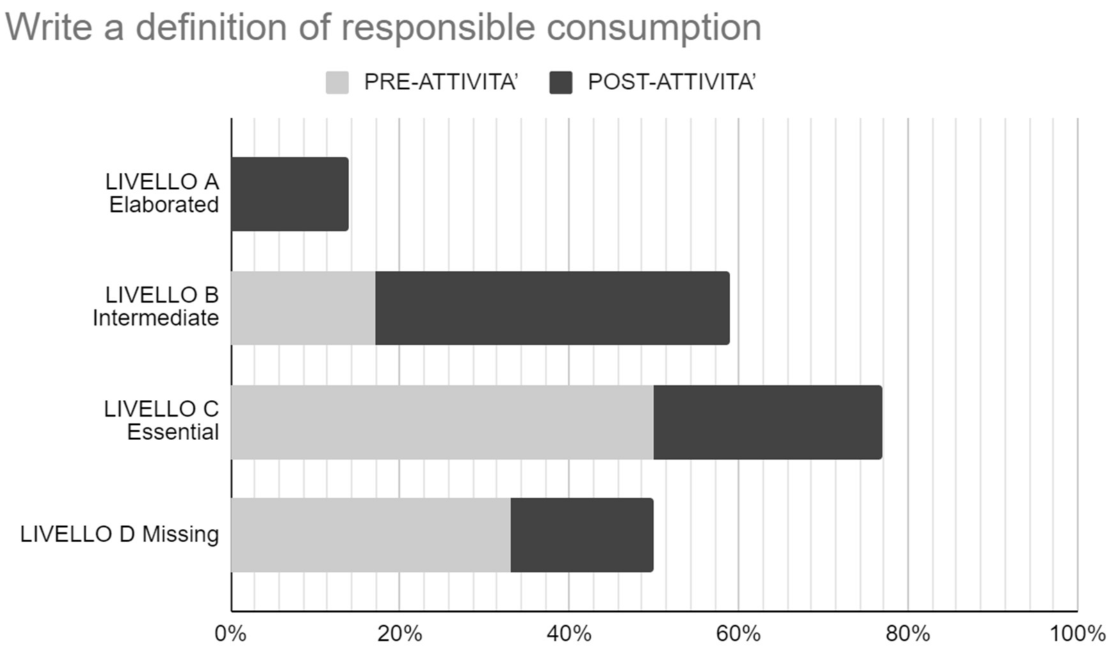


Fig.4.5. Pupils' definition of responsible consumption.

DISCUSSIONS

The experimentation allowed to highlight some points of interest, thanks both to observation of pupils working in the classroom and to data evaluation. During the didactic activity, pupils observed, measured, collected and interpreted data, starting from a practical situation on a real topic. The results corroborate the findings of a great deal of the previous work that suggest the effectiveness of active learning approach (e.g Sharma, 2016)). In fact, during all the activity, pupils demonstrated a high level of concentration, engagement and emotional involvement. According to Hedden (2017) *active learning* based on constructivism has been a strategic approach to address sustainability, also thanks to the relationships of the topics with reality.

The game-challenge and cooperative learning have been catalysts of students' learning and motivation. Pupils worked with enthusiasm and motivation thanks to the eye-catching challenge: to prepare the best menu. They discovered with surprise the strong environmental impact of everyday life behaviors, including eating foods. During the cooperative learning, they discussed a lot about their food consumption habits and the corresponding ecological footprint.

Before the activity, students already knew the importance of a Mediterranean and varied diet for human health. They already knew nutrients characteristics and food pyramids for human well-being. Moreover, they addressed nutrition topics only in Biology, in relation to the human body and digestive system study. On the contrary, they never addressed topics such as the water, carbon and ecological footprint of foods, especially regarding meat and non-local products. During the activity, pupils were very impressed, discovering the big amount of natural resources and carbon emissions related to food life cycle assessment.

The experimentation was carried out in the presence of Science and Geography class teachers who appreciated the didactic objectives and approaches used, cooperating with enthusiasm. Teachers had the role of facilitators and observators and expressed the desire to deepen the topic, involving other teachers too (Technology and Citizenship Education).

After the activity and thanks to the surprise effect of the game, pupils changed their way of thinking, looking at the food pyramid and healthy diet not only as a tool for achieving human well-being, but also as an individual challenge to save the planet. During and after the team work, students discussed critically among peers about their uncorrect overconsumption of meat rather than fruits and vegetables, as well as packaged products rather than unpackaged products. Moreover, the didactic approach allowed pupils to address sustainable food consumption in an interdisciplinary manner, starting from Geoscience topics. According to Orion and Libarkin (2014), the use of Geosciences allows to better address the change of environmental behavior. In fact, topics such as natural resources consumption, waste production and circular economy with their many interdisciplinary connections make Geosciences the major areas that can be used by teachers in conceptualizing sustainability (Hale, 2017). Infact, data showed a significant improvement in students' awareness about the ecological footprint of their consumption habits after the activity, especially regarding meat consumption and non local products. Analyzing questionnaire post-activity answers, most pupils linked a healthy diet, biological and rich in local products, cereals, legumes, fruits and vegetables to the safety of the Earth planet. Moreover, data show an evolution in the definition of responsible consumption, due to an increased awareness of the big amount of natural resources necessary for food production and the strong environmental impact too.

CONCLUSIONS

Food sustainability continues to become one of the big challenges of achieving sustainable development goals, especially when our common future is threatened by the challenges of food security and land degradation globally (Grindle et al., 2015). Issues such as growing food demand, energy scarcity, natural resources overexploitation and environmental pollution related to food production are becoming more and more critical (Pagotto and Halog, 2016; Manning and Soon, 2016). Nevertheless, actual society is trapped in a consumerist and individualistic culture that encourages people to buy more and more for their own better lifestyle. Marketing sometimes deceives citizens to be free and powerful thanks to their purchase-power. Consumers are often slaves of marketing policies and sometimes build their own identities on their purchase-power, including buying food. The need to have much more than is necessary is a common concern of developed countries, that often causes a big amount of food waste.

This scenario leads us to surmise that citizens are not sufficiently aware of the seriousness of the situation of our planet. Environmental problems such as deforestation, global warming and over-exploiting of fisheries, waste management among others, are not sufficiently visible for the majority of citizens to change their habits of consumption. Young people are consumers and belong to a small consumers' community (family and friends). The necessary change of mind among young people is to be free from marketing scenarios and learn to choose what they really need. Education for sustainability allows students to acquire knowledge about the ecological footprint of foods, in order to become aware of consumerism's impact on the environment. Teachers and educators have the role to promote a transformation process in consumers' behaviour, beginning from the bottom (young people).

Geoscience teaching has a key-role in the acquisition of responsible consumption habits. In fact, this change of mind could become possible only if students understand the need for responsible natural resources management. Knowledge about ecological footprint, carbon footprint and water footprint of every good and food is necessary to build a new generation's responsible lifestyle. If only educators try to make pupils overcome the widespread belief that consumerism is a tool to achieve their own personal gratification, the transformation can occur.

Didactical approaches based on active-learning and gaming could help teachers to achieve the big challenge of pupils' thinking transformation process, that allows them to approach and look at the real issues with the planetary health lens. It is very important that pupils feel integrated with the environment: the air they breathe, the water they drink, the food they eat and the waste they produce. Through activities that address topics near reality and require students' personal involvement, students can acquire new competencies about responsible lifestyles and eco-friendly behaviours. The team work and the gaming challenge ensure a high students' engagement, improving critical thinking that allows to address sustainability topics in a systematic and interdisciplinary way.

4.4 Activity C1- Sustainability through gaming- *The S-City Game cardboard version*

In this paragraph a paper, entitled “*Sustainable city game: an engaging ludic activity to introduce students to the Agenda 2030 Goals for Sustainable Development*”, shows results concerning “The S-City cardboard game” activity. The article briefly reports methods and approaches used to prepare the didactic activity, more widely described in par. 3.3.1 (*Materials and Methods*). The complete game set is reported in Annexes 7,8 and 9. *S-City* cardboard game is a serious game developed in order to approach Agenda 2030 and Sustainability topics, as explained in the following paper, at the 89° Conference of Italian Geological Society (Parma, September 2019). The numbering of figures and tables follows that used in this PhD thesis.

Congresso Nazionale Parma 2019
Il tempo del pianeta Terra e il tempo dell'uomo: le geoscienze tra passato e futuro
SIMP Società Italiana di Mineralogia e Petrologia
SGI Società Geologica Italiana
SOGEI Società Geochimica Italiana

SUSTAINABLE CITY GAME: an engaging didactic activity to introduce students the 2030 Agenda Goals for Sustainable Development

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ABSTRACT

The Sustainable City Game project (S-CITY GAME) aims on one side to introduce students to the themes of the exploitation and utilisation of georesources and on the other to the need of adopting a more sustainable lifestyle. S-CITY GAME has been realized in the frame of the Agenda 2030, to address topics such as clean water and energy, responsible consumption and production, actions for climate, circular economy, sustainable cities and communities. The multidisciplinary approach of the project allows to involve teachers of many disciplines, and might be especially useful

in Italian Middle School classes (ages 11-14), where time for laboratories is always limited and the teaching of Geosciences and Environmental Education always is penalised due to lack of time. Instead, this project shows how using a combination of geoscience topics and environmental problems, with inputs from other disciplines (both sciences and humanities) can allow students to acquire valuable geoscience knowledge as well as developing skills in active citizenship and increased environmental awareness. Regarding the game, starting from a conventional city, each team follows a path, step by step, in order to reach the heart of a sustainable city. The itinerary includes multiple choice quizzes, open tests, charades and word games. The topics proposed deal with the definition of georesources, their distribution and uses, the pollution, the concept of renewable and non-renewable resources. The posed questions offer also the possibility to reflect about simple but effective actions to take in everyday life to increase sustainable awareness. In this way students can become protagonists of the game and translate what they learnt in their everyday life, involving the school mates and also their families in the process. The multidisciplinary approach allows proposing questions in the game, where topics of history, geography, science, math and technology are closely connected, also offering links to literature, foreign languages and art.

The experimentations have been carried out both with teachers and with students. Results are very satisfying in terms of involvement of students as well as teachers.Expected outcomes include: a) to learn new concepts related to geosciences and the Agenda 2030; b) to acquire key competences of active citizenship for more sustainable lifestyles; c) to help students' mind to assimilate new content/information and modes of thinking in non-traditional ways; d) to promote pupils' divergent and critical thinking; e) to develop problem-solving skills.

KEYWORDS: Agenda 2030, Sustainable Development, teaching Geoscience, sustainable lifestyle

INTRODUCTION

"*The global approach of Agenda 2030 for Sustainable Development, adopted by the ONU General Assembly in September 2015, to fight poverty, inequalities and other global problems…closely links this plan with peace in the world*" (General Assembly ONU). General secretary of the United Nation Antonio Guterres describes the Agenda 2030 for Sustainable Development as a plan of action aimed to achieve globally peace and face multiple crises that affect our societies. In fact, natural resources overexploitation, unsustainable consumption and production, climate change and loss of biodiversity are serious concerns on a global scale, to be urgently tackled. This state of affair causes environmental, economic and social problems such as extreme poverty and inequalities (Tafuni et al., 2019).

Sustainable development is a program that provides long-term economic, social and environmental benefits while meeting the needs of present and future generations. In the 21st century it is one of the most important priorities of governments, organizations, businesses and civil society in general. The Agenda 2030 with its 17 Goals (SDGs) and 169 targets focuses on a set of global priorities to achieve Sustainable Development in five P-instances: People, Planet, Peace, Prosperity and Partnerships (de Paula, 2017). From this scenario, Sustainable Development concerns economical, social and environmental issues.

The strengths of the 17 Goals for Sustainable Development (SDG) are universality and the entanglement: they concern countries all over the world and they rely on each other. Furthermore, Geosciences can intersect the most with the topics of Agenda 2030 Goals such as (2) no hunger, (6) clean water, (11) affordable and clean energy, (12) responsible consumption and production, (13) climate action, (14) life below water, (15) life on land. All the Goals are interconnected and each one is necessary to fight poverty and hunger. Since the Agenda 2030 is a key plan of action to get to an equal and peaceful world society, the first step is to realize a prominent and guiding role in the rising collective social engagement on sustainability (Tafuni, 2019).

Education at all levels has this fundamental role, as indicated in SDGs'12.8 target, "*by 2030 ensure that people everywhere have the relevant information and awareness for sustainable development and lifestyles in harmony with nature*". The 2017 ONU General Assembly underlines everybody's required involvement in order to take action towards planet safety: "*We are determined to protect the planet from degradation, including through sustainable consumption and production, sustainably managing its natural resources and take urgent action on climate change, so that it can support the need of the present and future generation*" (UN, 2015).

Intergenerational equity is a key component, in order to balance the needs of present and future generations. In the last year, millions of students across Europe are raising their voices as decision makers following Fridays for Future movement (Tafuni et al, 2019). They expressed their right to have the sustainable future described in the Agenda 2030. According to the SDGs' 4.7 target, all people have the right to access knowledge and skills needed to promote sustainable development in order to build resilient and sustainable societies (UNESCO, 2013). For this reason, the role of education at school and especially Environmental Education is critical for promoting sustainable development and improving the capacity of people to address environment and development issues (UNESCO, 1992).

Over the course of time Environmental education evolved, redirecting its focus towards sustainability (Tillbury,1995; Gayford, 1991). Teaching sustainability improved itself shifting from "education *about* sustainability" (theoretical approach), to "education *for* sustainability" (aimed to change attitudes) and to finally achieve "education *towards* sustainability" (building the capacity to think and act critically in relation to sustainable development) (Mahruf, 2011). UNESCO defines Education for Sustainable Development as the education that "...*empowers learners to take informed decisions and responsible actions for environmental integrity, economic viability and a just society, both for present and future generations, while respecting cultural diversity*". Furthermore, UNESCO declares that "*With a world population of 7 billion people and limited natural resources, we, as individuals and societies, need to learn to live together sustainably. We need to take action responsibly based on the understanding that what we do today can have implications on the lives of people and the planet in future….to transform society by reorienting education and help people develop knowledge, skills, values and behaviors needed for sustainable development. It is about including sustainable development issues, such as climate change and biodiversity into teaching and learning. Individuals are encouraged to be responsible actors who resolve challenges, respect cultural diversity and contribute to creating a more sustainable world. Education for Sustainable Development (ESD) empowers people to change the way they think and work towards a sustainable future".*

Education for Sustainability (ESD) should be a high priority at all educational levels since environmental, economic and social problems undermine the future of the Earth (Tillbury, 1995; Gayford,1991). A large number of articles, books and reports now consider a key strategy to focus environmental education towards sustainability (e.g.: Huckle, 1990; Orr, 1992; Fien, 1993). The Italian *Indicazioni nazionali e nuovi scenari (*MIUR, 2017) stresses the necessity of an Education for Sustainability at all levels schools and the Italian School National Department formalized in 2019 a law for the integration of Citizenship Education in all School Curricula (MIUR, 2019). Sustainable development is one of the three key-pillars of this discipline.

The Sustainable City (S-City) game is an engaging ludic activity carried out using a board game, to be played in teams, planned for 11-14 years old students, the difficulty level of the questions proposed changing depending on the classes. This activity will soon be adapted also to be used with younger and older students (aged 10 and 15) as a related activity to the vertical curriculum (MIUR, 2017). A ludic activity represents an involving and challenging experience to catch pupils' attention and motivation (Quaglia, 2009). According to MIUR *Indicazioni nazionali e nuovi scenari* (2012), learning is a process and an experience of gaining both knowledge and new skills and competences. To engage in this act of gaining knowledge and skills, learners must be motivated. According to Chan & Ahern (1999), "*When people are intrinsically motivated to learn, they not only learn more, they also have a more positive experience*". Setting Educational Game (EG) has a great potential to support immersive and emotional learning experiences (Paras, 2005). Games can represent effective learning environments: they are active experiences and they are able to provide intrinsic motivation. In the game, as Paras (2005) underlines, reflection is incorporated into the immersive 'magic circle' of the game play. The act of pupils' reflection is incorporated both in game core mechanics and in the creative experience of the game world.

Why an educational game about a sustainable city? The majority of people currently live in cities and urban areas, and over 70% of the global population are expected to live in urban areas by 2050 (UN, 2020). The importance of cities is also expected to increase due to the role of metropolitan areas as growth centers of the emerging global service economy. Furthermore, cities play a dominant role in global consumption, production and pollution (Sukhdev, 2009). For this reason, "sustainable cities" and "aware citizens' lifestyles" have been identified as key topics for sustainable development and climate change.

The S-City Game project sparks student's interest in Agenda 2030 for Sustainable Development and its Goals. Knowledge construction occurs in a practical and transformative way. Throughout the promotion of globally responsible action-makers (de Paula, 2017) Sustainability is implemented in curricula. This activity is structured from the perspective of transdisciplinary education. This approach is essential for the multidisciplinarity of sustainability issues and for the valorization of non-fragmented knowledge, developing a holistic vision of the topic (Morin, 2003). Through the board game "S-City Game", students discover global and interdisciplinary issues, such as the SGDs goals and what their targets mean, natural resources exploitation, responsible consumption and sustainable lifestyles. The

SDGs 11 underlines that until 2030 urbanization will exponentially grow and everybody must improve new competencies of active and aware citizenship, in order to gain sustainability. Through the S-City game, students can learn sustainable simple everydaylife actions and lifestyles, in order to replicate them in their real life. The game is cross-disciplinary since it involves teachers of different matters in order to promote students' knowledge and expertises from different viewpoints, following an holistic path.

MATERIALS AND METHOD

The S-City Game is an educational board game on Sustainable Development. A board game is a useful tool to engage players in environmental issues thanks to players' active participation in the game and the knowledge obtained is in connection with Environmental science. S-City Game activity was carried out both with a group of 24 teachers (Science, Geography and Technology) during the "Geo Summer School 2019" dedicated to teachers' professional development and with 112 students (K6-K7 pupils).

At the end of the activity, both involved teachers and students were given a satisfaction questionnaire. The teachers' one investigated if they have ever addressed their pupils to the Agenda 2030 topics and on which occasion. Furthermore, teachers had to express their level of satisfaction about the proposed activity and were asked suggestions to improve the activity. The students' questionnaire investigated their familiarity with the Agenda 2030 topics and their involvement and satisfaction degree during the game. Both teachers' and students' questionnaires are composed of a series of statements to rank with Likert scale and by open-answer questions to highlight strengths and weaknesses in the activity. A 5-levels Likert scale was used to rate the agreement/disagreement on specific items (Stacchiotti et al., 2019). We report here some examples of statements or questions teachers' were supposed to rank or answer: "*Have you ever discussed the 2030 Agenda with your students? In which occasion?*", "*The 2030 Agenda topic is interesting and I'd implement this issue with my pupils after this activity*", "*The educational game S-City Game is a good approach to deal with 2030 Agenda goals topic*", "*Express your opinion about the strengths and the weaknesses of the activity*". The following statements were in pupils' questionnaire: "*The 2030 Agenda topics are interesting*", "*I appreciate S-City as an educational game*", "I *would like to use an educational game to address different topics and subjects*", "*Write particular aspect/s* *of this activity you like the most*", "*Write particular aspect/s of this activity you would like to change*".

The unique feature of the S-City Game is the interdisciplinarity. Infact, it proposes questions about topics of history, geography, science, math and technology that are closely connected, also offering links to literature, foreign languages and art. The objective of the four teams composed of 3-6 players each is to reach a Sustainable City starting from a traditional one, through a path of numbered boxes. The game equipment and an example of a card game are shown in Fig. 4.6.

The cardboard game, an example of pawn and dice are represented in Fig. 4.7 and in Fig. 4.8. In order to engage players as Agenda 2030 followers, each team is invited to choose a pawn marked with one of 17 SDGs. On their turn, each team rolls two dice and moves the checker of as many boxes as correspond to the subtraction of the gained scores. The dice are shaped like octahedrons, in order to represent one of 16 SDGs on each face. The 17 SDG (partnership for the goals) is a slogan used throughout the play-time to promote collaboration among pupils. Thanks to SDGs goals logo represented on pawns and dice, pupils' familiarity with the 17 Goals improves, as they play and play again. The numbered boxes have different colours or images because they represent different tasks to pass. After rolling the dice and moving on checkers, the teams arrive on a box and draw the corresponding card.

On each card a particular trial to overcome is written. These tests are multiple-choice questions or particular trials, such as, for example, to draw or to mime a sustainable action. If the playing team passes the test, moves on its pawn of two boxes, otherwise stays still in that position. This golden rule has a symbolic meaning: citizens must improve their awareness and responsibility in their lifestyles in order to reach future sustainability. Without a significant change in action there is no sustainable development. The trials of each kind of box are described in Table 4.2.

S-CITY GAME EQUIPMENT	
1.	Cardboard
1.	n. 2 dice
1.	n. 17 pawns
1.	n. 1 Stop-watch
1.	n. 120 Quiz-card (20 for each matter)
1.	n. 10 Individual mimo cards
1.	n. 10 Double mimo cards
1.	n. 17 Guillotine cards
1.	n. 10 Challenge head-to-head cards
1.	n. 10 Challenge team-to-team cards

Fig.4.6. S-City Game equipment list (left). An example of card game (right).

Fig.4.7. Cardboard S-City Game

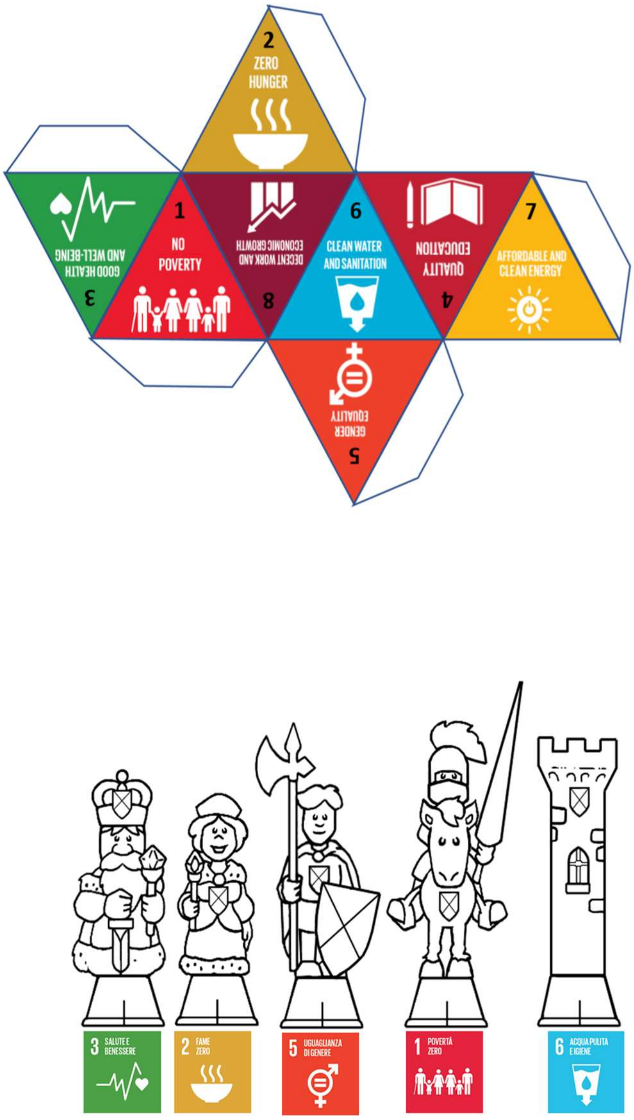

Fig. 4.8. S-City Game Dice (up). S-City Game examples of pawns (down).

Kind of boxes	Check to pass
Coloured boxes Multiple-choice quizzes about natural resources consumption, aware lifestyles, circular economy, pollution, climate change and other 2030 Agenda topics	Multiple-choice quizzes regarding to:
	History (red boxes)
	Science (green boxes)
	Maths (brown boxes)
	Technology (green boxes)
	Citizenship (yellow boxes)
	Geography (blu boxes)
Challenge head-to-head A player of the on duty team challenges someone he chooses from another team	Word games, scrabbles, crosswords anagrams, speed games ecc.
Challenge team against team The on duty team challenges another team of its choice	Word games, scrabbles, crosswords, anagrams, speed games ecc.
Guillotine	Analyzing 5 key-words, the on duty team must guess the SDGs corresponding.
Single mime/ double mime	One or two components of the on duty team must mime or a responsible everyday life action for sustainability or a key aspect of a sustainable city. The other components of the same team should guess.
Prison	Stop for one turn. The team can get out of prison through a particular test: guess a sustainable action sketched by a team-mate.
Goal boax	Role Play: “Invent your political party: name, logo, slogan, 3 key action-points of your political campaign”.

Tab.4.2. Different cardboard boxes’ description.

When a team reaches the GOAL box, they have to overcome the last trial, in order to be declared the winner. The other teams take part in this final step, in order to have a final ranking. The final challenge is a role play. In fact, each team is invited to play the role of political party’s members: in 15 minutes, each team has to invent the political party's name, logo, slogan and 3 most important points of their political campaign about Sustainability. Teams shared with the others their own political and environmental programme, and explained the reason for their choices. The winner and the final ranking will be declared according to teachers and pupils' satisfaction. Students' attitude along the game is carefully observed and noted everytime the activity is replicated, in order to highlight its strengthnesses and weaknesses. Thanks to researchers' critical observations, a little rules adjustment was applied when repeating the experience with a different class. For example, students get bored losing enthusiasm and motivation when the play time is stopped for a few minutes for explanations or discussions about new topics. Furthermore, the use of a stopwatch with alarm is necessary to improve students' motivation and concentration during the tests. At the end of the activity, a discussion allowed reflecting about responsible lifestyles in order to become aware citizens.

RESULTS

The S- City Game activity was carried out both with 112 students (k6-k7 pupils) and with a group of 24 teachers. Pupils were encouraged to play in close-knit teams, developing a positive competition attitude. In fact, the risk in team-game is that students lose sight of its educational purpose. To overcome this critical problem, teachers had the role of pupils' guide that encouraged fair play and mutual respect. Finally, the didactic activity was planned to verify if a geoscience-related activity could improve the interest in Geoscience trough Agenda 2030 topics, and could also indirectly contribute in improving multidisciplinary competences of the pupils using a practical and ludic application (Stacchiotti et al., 2019).

Teachers' contribution during the experimentation is to verify activity's effectiveness and collect criticism and useful suggestions. It was also utilized to investigate if they have ever discussed the Agenda 2030 Goals with their students and, eventually, how they linked this topic with their curricular programme. Furthermore, it was investigated if the proposed activity was interesting according to their teaching style and if the availability of ready to use tools can make the activity itself easier to be carried out at schools. The authors also asked teachers if a similar activity is more appealing to be proposed, for multidisciplinary links and follow-ups topics. In the following, we will focus on the activity at school and the obtained results, but some useful comments from the teachers involved in the testing will be discussed.

The data emerged from the evaluation of the forms completed both by the teachers and the students (satisfaction questionnaires after the activity) were analyzed, to gain information on the validity and effectiveness of the project. These data are referred to 24 teachers and 112 students involved in the activity.

Focusing on teachers' questionnaire results, the data show that most teachers have already discussed the Agenda 2030 topics with their pupils at least on one occasion, although with a general degree of explanation. Some teachers have addressed these issues with pupils discussing environmental and social problems such as climate change, poverty, hunger and pollution. S-City Game activity was satisfactory for most teachers (97%) who declared that it is an effective educational tool to vehicle the key principles of sustainable development and good practices of everyday life. Therefore, after the activity, all teachers expressed a high interest in the Agenda 2030 Goals topics that in the future they'd like to implement with their pupils. Strengths and weaknesses of the activity emerged from teachers' answers are shown in Table 4.3. In this table researcher's proposals of possible solutions to overcome the weaknesses are reported.

STRENGTHS	WEAKNESSES	SOLUTIONS FOR WEAKNESSES
Interdisciplinarity is a positive aspect Very actual issues are approached using everyday life actions Pupils' engagement and involvement are very high Students can improve their problem-solving, team-work and transversal skills Educational games are a tool to improve social competences (e.g., social rules as respect and good competition) There are contents to improve critical thinking	Large teams are difficult to manage (sometimes undisciplined behaviour occurs) Time is limited for the single teacher (few hours a week in one class) Additional work to assess students' performance	Teachers should be careful observers, to ensure the game rules are respected. Thanks to its character of interdisciplinarity, S-City Game activity should be carried out by teachers of different subjects increasing time and contributions Ongoing evaluation can be carried out through an observation grid

Tab. 4.3. Strengths and weaknesses of S-City Game activity in teachers' opinion.

Regarding students' questionnaire results, most pupils (94%) declared to have been very engaged in the Agenda 2030 topics thanks to the S-City game activity. Moreover, 94% of pupils are interested in replicating the activity with different teachers of the subjects related to the game questions (Fig.4.9). Fig. 4 shows students' opinion emerged from the analysis of the open-answer question: "*what did you like most in S-City Game activity*?", and 28% of students declared to have appreciated all the activity in general and were enthusiastic to have played with an educational game at school. 29% of students enjoyed working in a team thanks to an activity that involves all the class-groups. 26% of pupils declared to have appreciated mostly the final role play (final challenge) that, therefore, have been the most appealing and funny S-City Game's check to pass. The final trial was a winning idea (Fig. 4.10).

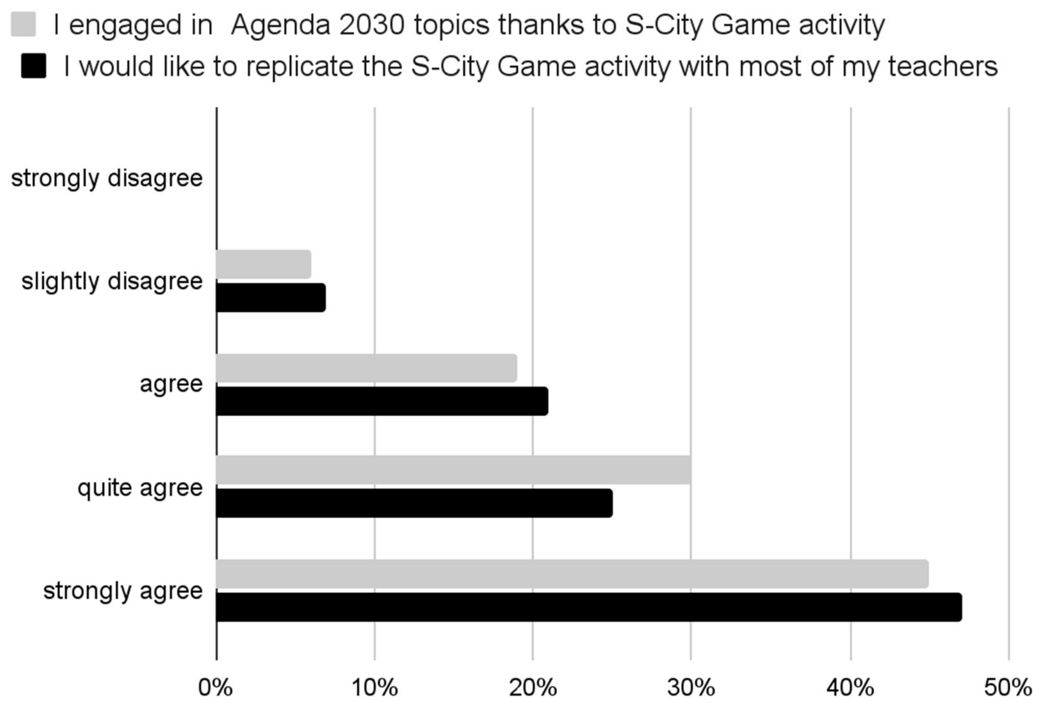

Fig. 4.9. Students' satisfaction questionnaires' results about S-City Game activity.

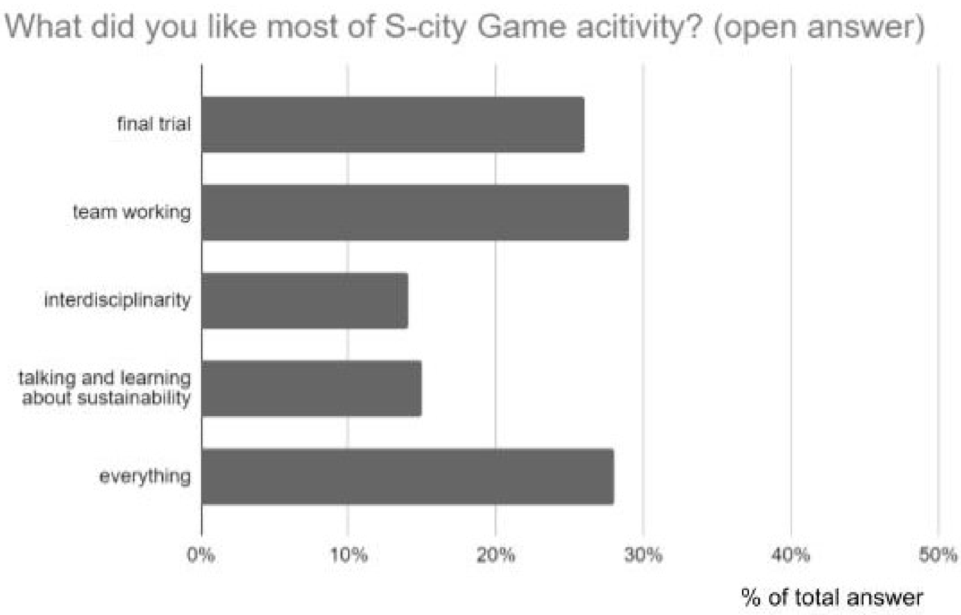

Fig. 4.10. Students' satisfaction questionnaires' results about S-City Game activity.

DISCUSSION

Although there is a wide literature on the educational value of gaming (e.g. de Castell, 2011; Van der Aalsvoort, 2014; Prensky 2011) the innovative aspect of this research is the topic (Agenda 2030, Sustainability topics, georesources exploitation, responsible consumption, circular economy), addressed with a learning-by-playing approach. A game about Agenda 2030 SDG has already been realized by ASVIS (https://go-goals.org/it/), but it is composed of very simple questions on the meaning of each SDG. These quizzes are not linked to the different school subjects, as in S-City Game, that involves Geography, History, Science, Math, Technology, Citizenship, in order to show how it is possible to address sustainability topics, with a particular attention to circular economy, georesources, responsible consumption, waste, climate change, in an interdisciplinary manner. Moreover, literature shows an example of a board rule- game about environmental education, but focusing only on climate change and actions to fight against it (Eisenack, 2012). Another example in literature is presented by Despeisse (2018) who developed a board game aimed to provide examples of technical and managerial practices for eco-efficiency and sustainability leadership in manufacturing. On the other hand, S-City Game suggests responsible actions and good practices to be adopted in everyday life of pupils and every citizen in general.

Some points of interest were observed during the experimentation with teachers and with pupils in the classroom and others were evidenced thanks to the data evaluation. The experimentation of the S-City Game activity allowed teachers to appreciate a board game as a useful and motivational tool to vehicle sustainable development topics. They were pleasantly impressed by the interdisciplinarity of the game and the assortment of abilities and competencies required by players. Regarding their viewpoints, the key concepts of sustainable development and sustainable lifestyles are very interesting thanks to their link with everyday life. Teachers also stressed that multiple-choice tests and trials allow students' reflection and critical thinking about how to change their future through simple good life practices. Furthermore, team working and game rules' sharing promote pupils' social competences improvement. Although some teachers stressed activity's weaknesses, the authors present simple solutions to overcome them, as described above in table 3. Overall, the S-City Game activity was significantly appreciated by teachers who expressed their wish to have this game available in their classrooms.

Regarding the experimentation with students, pupils demonstrated a high level of enthusiasm, but also an emotional involvement, possibly caused by the relationships of the topics with reality, which positively reflected on the acquisition of active citizenship competences. In fact, according to Chiariello et al. (2016) the playful and immersive nature of board games facilitated motivation, excitement and engagement of players. Furthermore, a board game allowed excellent results concerning growth of interest on Geoscience concepts linked with most of Agenda 2030 goals. The game activity as a didactic tool, the team working, the wide variety of ludic funny checks, especially the final challenge have been the winning ideas of the S-City Game. In fact, the higher pupils' involvement has been observed when the players discovered new concepts related to different subjects that increased their curiosity, as well as they get involved in the dynamic checks (mime, prison, challenge head-to-head or team-to-team).

The questionnaires' results stressed that the favoured trial was the final one. The game-role proposed in this challenge has been exciting and funny for pupils. They, in fact, had to overcome this task: "*Invent your political party: name, logo, slogan, 3 key action-points of your political campaign*". Teams demonstrated a high level of attention and concentration during the available time (15 minutes) and very good works have been produced. Each team shared its political campaign with the others, introducing very creative party's names, slogans and logos drawings. Furthermore, in most cases the three key-points of the political programme were completely addressed to environmental safe and sustainable actions, in line with the Agenda 2030 Goal adopted by the team itself. The teacher's interventions had the role of pupils' guide that encourages fair play and mutual respect, modulating competitiveness. Better playing behaviors have been observed when the necessary positive competition attitude without too much rivalry was stressed before the activity by teachers and researchers. The experimentation, in fact, highlighted that pupils had to gain awareness about the educational value of the game since the beginning. After the activity and thanks to a final discussion there was a pupils' mental change: most pupils realized that sustainable lifestyles are not an uthopic idea, but a real possibility. In fact, thanks to sustainable actions' practical trials, they realized that they could become aware citizens, changing simple everyday life attitudes.

As observed during the experimentation with students, the game must proceed continually, without interruptions and teachers' explanations of new concepts during playtime. In fact, in this scenario students are players, thus they are bored of any gamestop. Discussions about deepings of new and significant concepts has to be carried out after the activity, or else the play excitement and engagement cease. Therefore, the game has to proceed fairly quickly, using a stopwatching for every check.

CONCLUSIONS

The experimentation of the didactic activity with students approached them to the Agenda 2030 Goals topic in an active way. Pupils worked and discussed in teams, reflecting critically on natural resources overexploitation, waste production, circular economy and other key topics about Sustainable Development, starting from a playing situation. The pleasure in intellectual engagement, the joy in learning, in miming or drawing some good life practices and sustainable city's features are needed and useful vehicles for learning. The game asset made pupils protagonists of their own learning, since they were involved through several perceptual channels, as in the 3H concept, (Head, Hearth and Hands) Pennesi, 2017). The board games allowed a "learn by doing" approach (de Marcos, 2016) providing an hands-on and heads-on skill and knowledge improvement.

The use of Geosciences topics allowed to acquire new knowledge and competences about sustainability, with its many interdisciplinary connections, introducing students to the topics which are not commonly proposed in school, like also to the concept of circular economy. It is evident that it would be important to repeat this activity during the school year with other different teachers using this approach, aimed at contributing to the teaching of Education for Sustainability but also at improving the dissemination of Geoscience at school.

The use of a Sustainable Development topic allowed also to address complex and multidisciplinary concepts, which could be expanded to other actual issues, like the inequality in natural resources' distribution in the world and the consequent conflicts and migration phenomena. In the Middle school this activity represents a source of discussion during the scholastic year, with strong effects on long-term retention of contents and knowledge. For example, the history teacher addressed immigration issues connecting them with availability of resources and their exploitation, strengthening the concepts that emerged during the S-City Game activity. The activity was also effective in making the pupils aware of the human role on the planet, recognizing that Earth's resources are limited and that their unequal access and distribution are global issues.

The game also offers the possibility to reflect about simple but effective actions to take in everyday life for increasing sustainable awareness. In this way students can become protagonists of the game and translate what they learnt in their everyday life, involving the school mates and also their families in the process. As a direct consequence of the involvement of the students in the activity, they could become active change-makers and promoters of a new environmentally-friendly culture, at home and in the society.

4.5 Activity C2- Sustainability through virtual gaming- *The S-City digital Game*

As a follow-up work, a digital version of *S-City Game* was realized during the period of COVID-19 lockdown, when distance learning was a mandatory choice for all schools. This virtual version allowed us to test the activity with students and teachers from different Italian schools, obtaining interesting and useful results, as described in the following paper.

SUSTAINABLE CITY VIRTUAL GAME: HOW TO ENGAGE STUDENTS IN SUSTAINABLE LIFESTYLES

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ABSTRACT

The Sustainable City Game (S-City Game) is a game created to approach the United Nation Agenda 2030 and Sustainability topics. A cardboard version, already tested, has been translated as a digital version, for on-line school activities. This educational game aims to increase students' awareness about a more sustainable lifestyle, encouraging them to take action towards a responsible management of planet resources. The S-City virtual game has been created in a virtual world based on the 3D Opensimulator platform that can be accessed by teachers and students as avatars. Virtual worlds can offer new possibilities for education, teaching and learning formats and it was evident especially during COVID-19 pandemic, when most Italian schools adopted distance learning. In fact, S-City digital game, histed in the Techland virtual world, allows students to investigate, in an active way, topics like water saving, carbon footprint, ecological rucksack, circular economy and waste reduction, starting from daily routine actions, like eating and dressing. The game is planned to be played by K6-K10 level students. A multidisciplinary approach is used, with inputs from several disciplines, to have a holistic vision of the Sustainable Development Goals (SDGs). The game has been tested both with teachers and students, and the results are very satisfying in terms of involvement of students as well as teachers' interest. Students and teachers declared that it is an effective and engaging educational tool to vehicle the key principles of Sustainability and good practices in everyday life. This gaming approach allows students to acquire knowledge and key competences of sustainable

behaviours and active citizenship for eco-friendly lifestyles and to develop problem-solving attitude and digital skills.

KEYWORDS: Agenda 2030, Sustainable Development and lifestyle, Geoscience education, educational games, virtual worlds

INTRODUCTION

The essential role of Education for Sustainability

The biosphere is an intricate system of relationships, where small changes in one context cause chain reactions in many other areas. Although for a long time human beings have suffered the effects of complex dynamics and changings of environment, today human activity has become a central element in the characterization of these alterations (Butera, 2021). Not by chance, the present geological time has been named "Anthropocene" (Crutzen, 2006), to stress a phase of global history during which the actions of human beings are the principal cause of modification in planetary balances. From the middle of the 20th century to the present day, in fact, the rate of environmental changes caused by anthropogenic factors - including atmospheric concentration of CO_2 and other greenhouse gasses, ocean acidification, tropical forest and biodiversity loss - began to increase exponentially. Therefore, this period of time could be separated from the previous ones because of the human activity impacts on Earth that overcome those caused by natural processes (Gaffney and Steffen, 2017). Humans, because of their lifestyles, seem to have forgotten to be not an isolated species, separated from the environment. We are integrated with it, an integral part of the wider biosphere of Earth. Our impact on the planet is complex and rich in interconnected factors. The ways we produce and consume, move and organize urban and rural areas, develop energy and distribute it, cause a devastating impact on ecosystems and, consequently, on our well-being and our ability to survive. Among the several aspects of sustainable development, the link between human health and planetary health has an essential value. Therefore, the field of planetary health is not only about environmental science, but is cross-disciplinary, drawing on knowledge, literature and methodologies from geology, economics, ecology, anthropology, geography and politics (Cole, 2019).

The resources' overexploitation issue and, more in general, the effects of human activity on Earth balance have been known for a long time. In fact, since the beginning of 1800, scientific publications have highlighted that as living standards improved and the population increased, resources could become more and more limited (Malthus, 1826) and the environment so stressed by human activities that Earth's system would collapse. The “planetary boundaries'' concept was proposed by Rockstrom (2009) as quantitative limits within humanity can continue to develop and prosper, keeping the Earth system in a certain state of balance and stability. Overcoming them increases the risk of generating irreversible environmental changes. Among the processes that affect these limits there are, for example, climate change and ocean acidification, global use of freshwater and land use change.

Looking at this global scenario, education has a key-role in a social transformation process, in the way of thinking, acting and living. The United Nations Decade of Education for Sustainable Development (2005-2014) sought to mobilize the educational resources of the world to help create a more sustainable future. Education for Sustainable Development (ESD) empowers learners of all ages with the knowledge, skills, values and attitudes to address the interconnected global challenges we are facing, including climate change, environmental degradation, loss of biodiversity, poverty and inequality (UNESCO, 2019). Learning must prepare students and learners of all ages to find solutions for the challenges of today and the future. Education should be transformative and allow us to make informed decisions and take individual and collective action to change our societies and care for the planet. The world needs students who are able to understand how every human activity affects the social and environmental context and vice versa, developing plans of action that could improve the quality of life with a positive impact on the planet. Here the indispensable role of education for sustainability that is an integral part of the Italian school curricula nowadays. Citizenship education has become a mandatory discipline for all Italian schools and one of its three key-topics is exactly the Agenda 2030 for Sustainable Development.

The Agenda 2030 and its 17 Goals and 169 targets is an international plan of action aimed to achieve global peace, justice and equity fighting hunger, poverty and environmental degradation (UN, 2015). This agreement is based on the five pillars of Sustainability: People, Planet, Peace, Prosperity and Partnership. The multidisciplinarity and the connection with daily life of sustainability topics teaching need didactic activities based on active learning and interdisciplinary approach. If the task of education is to train aware citizens of the present and future world in the name of sustainability, the learning necessary has to be constructive and participatory.

Geoscience topics represent the key to approach environmental and sustainability issues, such as climate change, water and air pollution, georesources exploitation, and energy. In fact, Geosciences address students to complex topics, accompanying them to deepen environmental problems of the area they live in. Therefore, it is important to use these connections and improve Geoscience teaching in order to acquire valuable knowledge as well as developing skills of active citizenship and increased environmental awareness.

Gamification to foster learning about sustainability

Nowadays, it is understood that in order to deal with and engage in sustainability, more is needed than just knowledge concerning sustainable development (Tillbury, 2004). Education for sustainability demands approaches and learning environments promoting and facilitating the development of system thinking and learning for complexity of the social, economical and environmental areas.

Digital games can highly benefit learning for complexity (Fabricatore, 2012). One of the fundamental challenges of ESD is its goal to integrate science, social sciences and managerial science into one overarching systems thinking framework (Dieleman, 2006). This is basically a cognitive challenge that is fundamental. We are used to learning new concepts, taking things apart, deconstructing and analyzing them. We usually focus more on the parts than on the whole. On the contrary, sustainable development requires us to understand the effects of one dimension on the other dimensions and on the whole. However, since we are so poorly equipped to think in systems terms and to comprehend systems behavior, we are tempted to deconstruct systems and to analyze the parts. One of the key challenges of ESD education is to develop a ‘systems thinking language.’

Playing games is an appropriate activity in the context of learning for sustainability and especially in the context of experiential learning that helps to approach the complexity of the world. When one plays games, one simulates and creates realities with all their complexity, mutually accepting rules, roles, conditions and assumptions. When one plays games, one can easily ‘take the role of others’ and develop an emotional understanding of why others act as they do. The beauty of playing games is that one ‘learns by doing’ and ‘learns by failing’ without negative consequences for the real world. One can simulate certain realities, play, manipulate and experiment and experience what the consequences are or what they might be.

An educational game prompts students to acquire new knowledge and skills thanks to an engaging and funny approach. A ludic activity always represents an involving and challenging experience to catch pupils’ attention and motivation.

Students are intrinsically motivated to learn, so they not only learn more, but also have a more positive experience (Chan, 1999). Setting Educational Game (EG) has a great potential to support immersive and emotional learning experiences (Paras, 2005). Games represent an effective learning environment: they are active experiences and they are able to provide intrinsic motivation. Pupils critical thinking is incorporated both in game core mechanics and in the creative experience of the game world.

According to Lee and Hammer (2011), games are motivating because of their impact on the cognitive, emotional and social areas of players; and so, gamification in education should also focus on those three areas. In the cognitive area, a game provides a complex system of rules along with a series of tasks that guide players through a process to master those rules. The impact on the emotional area works mainly around the concept of success and failure (Dominguez, 2013). On one hand, when players complete tasks, they are expected to have positive emotions by their mere fact of overcoming difficulties. Games try to assure and increase those feelings with reward systems that give immediate recognition to players' success, awarding them with points, trophies or items on task completion (Dominguez, 2013). On the other hand, when players fail, they can try again until they are able to overcome the tasks; a little feeling of anxiety can drive the players, motivating them. When multiple players interact through the game, these interactions have an impact on players' social area. Digital games offer a wide range of multiplayer interaction mechanisms which are integrated in the rules of the system. These mechanisms make it possible for players to cooperate helping each other towards a common goal, or just to interact socially by talking and writing.

Why an educational game about a sustainable city? More than half of the world's population now live in urban areas, and over 70% of the global population are expected to live in urban areas by 2050. According to Abu-Rayash (2021) the importance of cities is also expected to increase due to the role of metropolitan areas as growth centres of the emerging sustainable economy. Furthermore, cities play a dominant role in global consumption, production and pollution. For this reason, sustainable cities and aware citizens' lifestyles have been identified as a key for Sustainable Development and climate change. Players cover the role of citizens in a smart city, so they have to acquire lifestyles and behaviors in line with sustainability principles.

Play games in virtual worlds, precious didactic tools for distance learning during COVID-19 pandemic.

Virtual worlds are digital spaces accessible by users in the form of avatars (a digital representation of one-self) using a user graphical interface, called viewer (Schroeder,2008). Since the beginning, educators have explored their great potential to foster learning (Littleton, 2008), (Allison, 2012) using constructivist methodologies like cooperative learning and learning by doing (Gul, 2012). A virtual world is a "metamorphosis" of our world, with people, objects, places, and providing various forms of interaction between these objects and people, represented by avatars (Kamienski, 2008). Since then it became clear to teachers and researchers that virtual worlds can offer new possibilities for education, teaching and learning formats. In particular, the 3D platform Opensimulator (opensimulator.org) offers interesting features to support these methodologies (Dalgarno,2010). One of these features is the interactivity. It is possible to give behaviour to the objects by inserting programs in LSL (Linden Script Language) with a special editor embedded in the viewer (http://wiki.secondlife.com/wiki/LSL_Portal). Objects can move, change size and color, become transparent. Furthermore, they can give notecards, images and interactive menus with multiple choices and can link to external web resources. In a virtual scenario it is possible to explore educational paths, role play or take part in an educational game as S-City Game. Moreover, to avoid the spread of the COVID-19 crisis, many countries worldwide have temporarily shut down their schools. National and international closures affect over 91% of the education community of the world. E-learning is the only effective manner for schools to coordinate the learning process during the global lockdown and quarantine period. Many schools have instructed their students through remote learning technologies to face the effect of local closures and promote the continuity of the education process.Therefore, virtual environments could represent an effective digital tool to engage students in a participatory and active manner, despite the distance learning.

The S-City game as an educational tool for sustainability topics

The S-City Game is an educational game, created to approach the UN Agenda 2030 and sustainability topics, in order to increase students' awareness about a more sustainable lifestyle. Through deepening knowledge about exploitation of georesources, clean energy, responsible consumption and production, actions for climate, sustainable cities and communities, they are encouraged to take action towards a responsible management of planet resources.

It is planned to be played by K6-K10 level students, in teams or individually. Starting from pupils' daily routine actions, like eating and dressing, the game allows them to investigate topics like water saving and carbon footprint, ecological rucksack, circular economy and waste reduction, using a multidisciplinary approach, with inputs from several disciplines, which allows to have a holistic vision of the SDGs. In fact, the game's unique feature is that quizzes and tasks address sustainability in an interdisciplinary manner, dealing with topics of History, Geography, Science, Math, Technology and Citizenship, interconnected with each other. This game characteristic offers a multi and interdisciplinary view of the five pillars of sustainability and links also to Literature, Foreign Languages and Art topics. The questions allow pupils to reflect about simple but effective actions to take in their everyday life for increasing environmental sustainability.

The first version of S-City Game is a cardboard game, planned to be played by four teams at school. Each team has an itinerary to follow in steps, to reach the heart of a sustainable city, starting from a conventional city. The itinerary includes individual and team challenges as disciplinary multiple-answer quizzes and mini-games.

During the COVID-19 pandemic, most Italian schools have adopted distance learning. Therefore, a digital version of the game has been created in a virtual world based on the 3D Opensimulator platform that can be accessed by teachers and students as avatars. The game resides in a virtual island, the Sustainability Hub (Occhioni, 2021) where an educational path about sustainability has been developed using 3D interactive learning objects, online web games, multimedia presentations and external web resources. This island is part of the virtual world Techland, focused on Math and Science (Occhioni, 2017). Moreover, a digital game inside a virtual world allows students to train and improve digital skills, according to the guidelines for Citizenship Education in Italian schools (MIUR, 2019).

Finally, the didactic activity was planned to verify if a geoscience-related activity could improve the interest in Geoscience through Agenda 2030 topics, and could also indirectly contribute in improving multidisciplinary competences of the pupils using a practical and ludic application (Stacchiotti, 2019).

MATERIALS AND METHODS

S-City virtual Game has been tested both with K6-k8 students (totally, 69) and with their teachers (24). Most teachers (83.3%) were not familiar with virtual worlds, so an initial training to master how to move and interact in the world was necessary. During this phase, teachers acquired the basic skills to use their own avatar and interact with virtual objects. On the contrary, students didn't need a lot of explanations to move in the world because of their better familiarity with digital games and virtual worlds. Students and teachers were given a questionnaire in order to collect data for the experimentation (pre- and post-activity for students, only post-activity for teachers). The teachers' survey investigated if and how they have ever addressed their pupils to the Agenda 2030 topics. Furthermore, teachers expressed their level of satisfaction about the proposed activities and were asked to give some suggestions to improve them. The students' questionnaires investigated their familiarity with the Agenda 2030 topics and their involvement and satisfaction degree during the game. Both teachers' and students' questionnaires were composed of a series of statements to rank with a 5-point Likert scale and by open-answer questions to highlight strengths and weaknesses in the activities.

Game structure

Sustainability City Game first version was a cardboard one, to be played by 4 teams composed by 3-6 players. It is very similar to the Game of the Goose. Each team has an itinerary to follow in steps, to reach the heart of a sustainable city, starting from a conventional city. The itinerary includes individual and team challenges as disciplinary multiple-answer quizzes and mini-games.

The virtual version of the game was developed in line with the cardboard one, but some adjustments have been made in order to adapt the activity for a virtual environment. It is planned to be played in teams (maximum 6) or individually. The avatars/players are the pawns of the game and move on the board game after rolling the dice (Fig. 4.11).

Fig. 4.11. S-City virtual Game.

At the beginning, players have to choose one of the 17 SDGs, in order to engage players in Agenda 2030 Goals for achieving Sustainable Development. Therefore, avatars wear a hat marked with the chosen SDG and take place on the corresponding box in the series that is in front of the board game. The team that plays first is that with the avatar located on the left side of this series and the round of gaming proceeds from the left to the right side. Each team is composed by 4-5 avatars that change during the game (in each game turn), in order to involve each component of the team in the activity as much as possible. Dice is shaped like an octahedron, in order to represent one of 16 SDGs on each face. The last SDG (17-partnership for the goals) is not considered but it is used as a slogan throughout the play-time to promote collaboration among pupils. The numbered boxes have different colors or images because they represent different tasks to pass.

After rolling the dice, the avatars move on the board and click on the landing box to start every task. Through an interactive panel and text chat, players can answer the questions or accomplish tasks. Some tests of the game are carried out using online educational apps, or sharing online interactive whiteboards.If the playing team passes the task, it can move on its pawn/avatar of three boxes, otherwise it stays still in the same position. This golden rule has a symbolic meaning: citizens must improve their awareness and responsibility in their lifestyles in order to reach future Sustainability. In Tab. 1 the various tasks are listed explaining what they consist of and how they must be overcome.

Boxes / Task to perform
Coloured boxes (disciplinary quizzes) Multiple-choice quizzes about natural resources consumption, aware lifestyles, circular economy, pollution, climate change and other Agenda 2030 topics. Quizzes are triggered by clicking on the landing box regarding to: - History (red boxes) - Science (green boxes) - Math (brown boxes) - Technology (gray boxes) - Citizenship (yellow boxes) - Geography (light blue boxes)
The Challenge All the players resolve online web app games directly from the virtual world (Word games, scrabbles, crosswords anagrams, speed games etc.)
Guillotine Analysing 4 key-words, all the players must guess the SDG corresponding, answering via an interactive menu.
Guess the action Starting from a partial image representing a sustainable action, all the players have to guess that action, by clicking on an interactive menu.
Prison Stop for one turn. The player can get out of prison through a particular test: to draw a sustainable action using a shared online whiteboard directly from the virtual world.
Final Challenge - Arrival box Role Play on a shared whiteboard making a collage of digital texts, images and drawings. *Imagine an electoral campaign to support your adopted SDG*. Each player has to write the name, logo, slogan of their environmental movement and 3 key action-points of its campaign. Players have to share with the others their own program, explaining the reason for their choices.

Table 4.4. Description S-City Digital game tasks

In the cardboard game, players drew the cards and read questions: on the contrary, in the virtual version questions and tasks appear on interactive panels and teams answer via chat. The task “Challenge” consists of online games, while the

“Prison” and the “Final challenge” task uses a shared whiteboard. When a team first reaches the final box, this team and all the others have to overcome the final challenge. The winner and the final ranking will be declared according to teachers and pupils’ satisfaction degree regarding the results of this final challenge.

In each session of the game experimentation, the authors (with the help of the participating teachers) carefully observed and noted students’ attitude and engagement, in order to highlight strengths and weaknesses of the game. These observations aimed to gather information for future game improvements. For example, a time counting and a timer for each task was determined to be necessary, to make sure that the play proceeds quickly. This fact allows pupils to really enjoy themselves during the activity, avoiding that they get bored, losing enthusiasm and motivation. Eventual explanations and deepings of the topics must develop at the end of the game. Finally, students were encouraged to participate in a debate to reflect critically on responsible lifestyles to become aware citizens.

RESULTS

The data, emerged from the evaluation of the questionnaires completed both by the teachers and the students, allowed to gain information on the validity and effectiveness of didactic activities proposed and the use of a game to vehicolate them.

EXPERIMENTATION WITH TEACHERS

During the experimentation, teachers appreciated both the contents and the graphics of the virtual game. Focusing on teachers’ questionnaire results, the data show that most teachers (70%) have already discussed the Agenda 2030 topics with their pupils at least on one occasion, although with only a general degree of explanation, during ordinary lessons. Only some of the teachers declared to have addressed these issues through an interdisciplinary approach. S-City Game virtual activities were satisfactory for all teachers and all of them declared that it is an effective educational tool to vehicle the key principles of Sustainable Development and good practices of everyday life.

From the analysis of teachers' satisfaction about the cardboard version of the game, its strengths were mainly interdisciplinary, pupils' engagement and improvement of social and critical thinking competencies. For the virtual version, in addition to these positive impressions, other strengths emerged, as shown in Tab. 2. In this table weaknesses of the activity are indicated and possible solutions for these weaknesses are proposed too.

STRENGTHS	WEAKNESSES	POSSIBLE SOLUTIONS for weaknesses
Interactivity Engaging virtual scenario (33.3% agree, 66.7% strongly and completely agree) S-City virtual game can be played at a distance	Sometimes it is difficult to move across the different parts of the game (33.3%), slowing down playtime Sometimes rules are difficult to apply using the interactive panel (37.5%), causing the game to slow down(22.2%)	An extra-time devoted to the teachers' training before playing can be organized The interactive panels are managed by a programming language; therefore players have to respect their turn of the game and to press buttons only if it is necessary. An extra-time for teachers' training can be provided before playing with tutorial of the game

Table 4.5. Strengths and weaknesses of S-City virtual Game activity in teachers' opinion (answers in brackets).

EXPERIMENTATION WITH STUDENTS

The virtual game allowed students from schools in different Italian regions to address sustainability topics in a funny and enjoyable way. During the experimentations, students were pleasantly involved, showing a high level of emotional involvement and enthusiasm, thanks both to the interesting topics (linked to real life) and the didactic approach used. More in detail, the intersection of virtual-based activities and gaming as a didactic approach fascinated students who felt the "sense of presence" in the virtual world and a high involvement during all the activity. Regarding students' data satisfaction-questionnaire results, most pupils (more than 95%) declared, as expected, that the virtual version of S-City Game is an engaging activity to address Agenda 2030 topics. Furthermore, pupils appreciated both the graphical design and the virtual scenario of the game (85.7% pupils). More than 85% students declared it was easy to apply the rules of the game, interacting with the different panels. This percentage is higher than the teachers' one (62.5%), as expected given the students' greater familiarity with computer tools and the digital divide between teachers-students. Students' open answers highlight that interdisciplinarity, team working and the final challenge are the main strengths of the activity. Answering the question "*did you enjoy the task challenge, disciplinary quizzes, guillotine, …*?"pupils answered that all the game trials (70% answers range are agree-completely agree) were mostly fun and interesting. Analyzing the pre-activity and post-activity pupils' answers, some data about the learning effectiveness of the activity were collected. In Fig. 4.12 students' percentage of correct answers about sustainability topics definitions are reported, showing a much better performance after the activity.

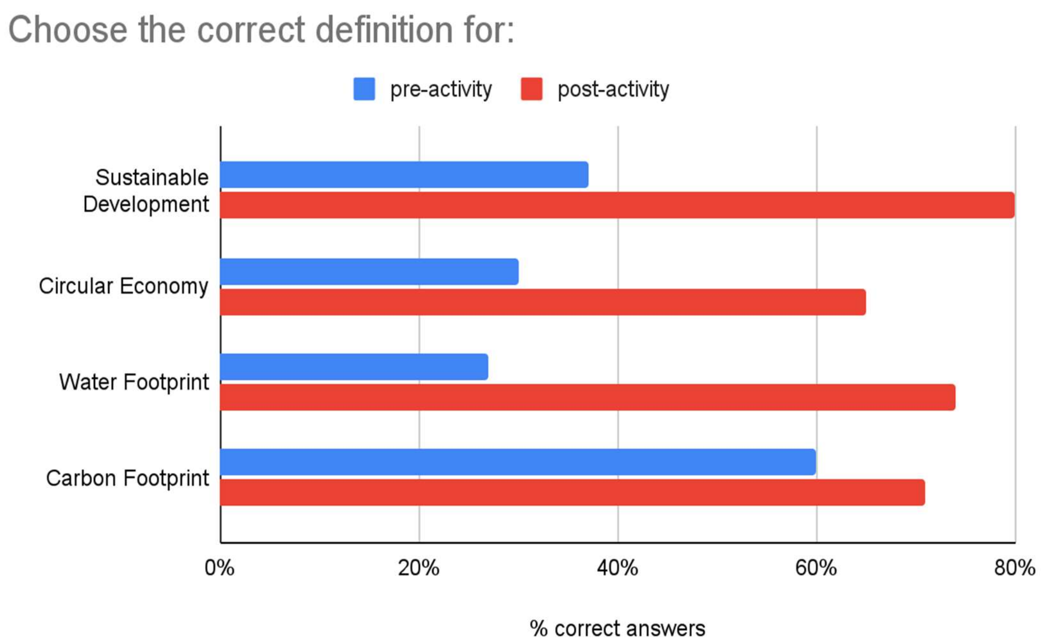

Fig. 4.12. Percentage of pupils' correct answers about sustainability topics in pre- and post-activity questionnaire

Furthermore, pupils' awareness about the importance of responsible resources consumption and circular economy improved. For example, after the activity, most pupils recognize that soil and minerals are resources, and 54% of pupils think about the fact that even waste can represent a resource. The open-answer questions: "*how is your ideal sustainable city*?" and "*what would you do in your everyday life as a citizen of a sustainable city*?" allowed researchers to collect pupils' opinion. Tab. 3 reports the main topics emerged from the surveys.

My sustainable city	Citizens in a sustainable city and their lifestyles
-clean energy (39%) - green areas (35%) -social equity and dignity (26%) -responsible resources management (26%) -responsible waste managemaìent (22%) -transports with lower carbon emissions (22%) -decrease pollution (19%) -clean areas and roads (13%)	-Recycling the waste (44%) -Reduce water waste (38%) -Moving by bike or walking (25%) -Keep the common areas clean (24%) -Reduce plastic utilization (22%) -Reduce domestic power consumption (16%) -Stop food waste (13%) -Reuse objects (12%) -Responsible food consumption (7%)

Tab. 4.6. Students' thinking about the main features of a sustainable city and its citizens' lifestyles.

DISCUSSION

Some points of interest were observed during the experimentation with teachers and pupils and others were evidenced thanks to the data evaluation.

The experimentation of the S-City Virtual Game activity allowed teachers to appreciate a digital game as a useful and motivational tool to vehicle Sustainable Development topics. They were pleasantly impressed by the interdisciplinarity of the game and the assortment of abilities and competencies required by players. Most teachers declared that, before the activity, had addressed sustainability with pupils only in a general way, without a well structured didactic path based on interdisciplinarity. Therefore, teachers appreciated S-City digital Game as a ready-to-use tool and expressed their wish to visit the Sustainability Hub island with their avatars and pupils' ones in order to replicate the game activity in their classrooms and in distance learning. Although some teachers stressed activity's weaknesses, the authors presented simple solutions to overcome them, as described in table 4.5.

The experimentation of the didactic activity with students approached them to Agenda 2030 Goals topics in an active way, although in the distance learning mode. Analyzing the pupils' satisfaction degree, they enjoyed the game, appreciating all the tasks in the same way. They declared to have a lot of fun and to have been pleasantly involved during all the game time. The team works well to overcome the trials without, in fact the team's components could easily talk and discuss the answers through digital resources such as microphone and chat. Regarding the pre- and post-activity questionnaires, a students' better performance was observed after the activity, especially in giving definitions about topics related to sustainability (e.g. water footprint and circular economy). Therefore, the S-City digital game has been evaluated as an effective tool to vehicle new concepts and improve new competencies, using distance learning. Despite the COVID-19 lockdown and school closing periods, , the researchers could actively involve students from different Italian regions, ensuring cooperative learning, problem solving and critical thinking. Digital tools such as virtual platforms, microphone and text chat, allowed pupils to discuss and interact with teachers and their peers, developing social skills in spite of the lockdown.

From pupils' opinion about their ideal sustainable city features and how they could act as aware citizens, some points of interest emerged. First of all, in addition to the common idea of green and clean cities, key-principles of a circular economy emerged. In fact, responsible waste management (also food waste), responsible use of resources such as water and energy and reuse of goods and objects are usual contents in pupils' opinion. Another important aspect is that social issues, like equity and dignified life for all (a core topic in Agenda 2030) are listed among the main features of a sustainable city and this result shows pupils' awareness about the multidimensional approach of sustainable development.

CONCLUSIONS

In education for sustainability, knowledge is important, but how students can apply that knowledge is more important. Attitudinal instruction and learning is more challenging than providing and gaining cognitive knowledge (Janakiraman, 2020). Simple pro-environmental changes in lifestyles always need a persuasive approach or pedagogical tool, in order to make pupils acquire performing behaviors in the real world. Traditional methods of instruction involving lectures, transmissive lessons and tests will only ensure cognitive knowledge gain. On the contrary, an immersion in a game context that involves students in facing real issues, is more effective. The pleasure in intellectual engagement, the joy in learning and discussing good life practices and sustainable city's features is needed and useful, in pursuing understanding with passion and the exhilaration we see in fully rapt attention (de Castell, 2011). The game allowed a "learning by doing" approach providing hands-on and heads-on skill and knowledge improvement. The game asset made pupils protagonists of their own learning, since they were involved through several perceptual channels.

This game allows students to address Sustainable Development topics in a multidisciplinary manner, embracing an holistic approach. The tasks require problem-solving abilities, in order to deal with global actual issues, not only environmental, but also social such as the inequality in natural resources' distribution in the world. In Middle schools this activity represents a starting point for discussion during the school year, with strong effects on long-term retention of contents and knowledge. For example, the History teacher can address immigration issues connecting them with availability of resources and their exploitation, strengthening the concepts that emerge during the S-City Game activity. The activity was also effective in making pupils aware of the human role on the planet, recognizing that Earth's resources are limited and not equally distributed among different countries. The game offers also the possibility to reflect about simple but effective actions to take in everyday life to increase sustainable awareness. Students are protagonists of the game and of their own learning. Therefore, they can contribute to the dissemination of Sustainability issues among peers and families, becoming active change-makers and promoters of a new environmentally-friendly culture.

Furthermore, S-City game has proven to be a successful educational tool for growing interest in Geoscience topics that concern most Agenda 2030 goals. The choice of Geoscience-related topics allowed students to acquire new knowledge and competences about Sustainability, with its many interconnections with Geosciences. Despite the distance learning, adopted by Italian schools during COVID-19 pandemic, the virtual game has been an effective tool to realize didactic experiential activities allowing students to work in a team, discuss each other through chats, and learn in an active way.

ACKNOWLEDGEMENTS

Special thanks are due to the teachers who collaborated by participating in the experiment with their students, giving suggestions and comments useful to improving the game.

4.6.1. Sustainability Hub- Experimentation with teachers

The following paper, entitled "*TEACHING sustainability topics in virtual worlds. A preliminary study"* was presented at the conference ESERA 2021.

TEACHING SUSTAINABILITY TOPICS IN VIRTUAL WORLDS.

A PRELIMINARY STUDY

Education for Sustainability may contribute to the real change of mind among students who could become action-makers towards a social transformation. Virtual worlds can help learning Sustainability topics offering a rich learning environment to explore, collaborate and interact. This paper presents a preliminary study to experiment how virtual words can help middle school students to achieve a global point of view about Sustainability, using an Opensimulator platform. The experimentation was carried out with a 21 teachers' group. They explored the educational paths, interacting with objects, reading in-world and web-resources, playing online games and running quizzes. Results show that teachers found the Sustainability Hub, created for this activity, as an involving, interesting and well-organized educational tool to approach Sustainability topics.

Keywords: Computer Supported Learning Environments, Teaching Innovations, Science Education.

INTRODUCTION

The multi-dimensional approach of Agenda 2030 Goals for Sustainable Development (SDGs) towards eradicating poverty and reaching peace is the greatest global challenge of our time (UN, 2017). In fact, SDGs give a new impetus to our collective development aspirations, covering a wide range of issues such as poverty, hunger, health, education, sustainable energy and cities, sustainable consumption and production, climate change, forests, oceans, and peace. The Target 4.7 gives education a key-role to promote a sustainable development and lifestyles (UN,2015; Ferreira et al., 2007). As the links between humans and nature relate to the health of our planet, education for Sustainable Development becomes necessary in all school curricula and allows pupils to enhance their knowledge, skills, and abilities to behave in a more sustainable manner (Merritt et al., 2019). Therefore, education for Sustainability may contribute to the real change in the minds of students, through well-planned didactic activities, facilitating the societal transformation process the Agenda 2030 requires.

Learning sustainability in virtual words

A virtual world is a "shared, simulated spaces which are inhabited and shaped by their inhabitants who are represented as avatars. These avatars mediate our experience of this space as we move, interact with objects and interact with others, with whom we construct a shared understanding of the world at that time" (Girvan, 2018). Nowadays there is a growing interest in the use of virtual reality environments because "through immersive education participants can be offered a feeling of 'being there', through a synchronous connection that allows them to communicate with a sense of presence" (Contreras-Mendieta et al., 2018). Among virtual worlds, OpenSimulator is an open-source platform highly customizable, used also for educational purposes for collaboration, simulation, and experimentation (Gregory et al., 2016), suitable also for studies about Geoscience education (Paris et al, 2020).

METHODS

A section dedicated to environmental Sustainability and the UN Agenda 2030 has been created in an Opensimulator-based virtual world (www.opensimulator.org) (fig.1). This section is made up of a group of islands each one deals with a different aspect of Sustainability (i.e. Agenda2030 and Sustainability goals, waste management, energy, urban sustainability, water management). This research focuses on testing the Sustainability Hub island, a sort of welcome area for teachers and 11-13 years old students, where they can first approach environmental Sustainability topics and retrace the path that led to the definition of the SDGs. Sustainability Hub is also the "hub" for reaching the other islands. In each section it is possible to find engagement questions for pupils, interactive objects, multimedia presentations, links to external resources, online games, practical activities for pupils. At the end of each section, it is possible to play an interactive quiz that provides a badge to verify new pupils' competences.

A group of 21 teachers (in different sessions), participated to the testing of the Hub, logging in the world from their home, using a viewer (firestormviewer.org). After an initial training to master how to move and interact, they were free to explore the educational paths for 2 hours, interacting with objects, reading internal and external resources, playing online games and running quizzes.

RESULTS

Sustainability Hub is structured in 6 sections which can be followed both sequentially and randomly.

In the “Welcome area” (section 1) the instructions relative to each kind of learning object in the various sections are described. In this area a map of the island and the teleport panel to transfer to the other islands in the "Sustainability" section are shown. In the “Sandbox” students can experiment with building.

In section 2, "The Current world scenario, students may approach topics like overpopulation, hunger and poverty, over-exploitation of resources, increase in greenhouse gases in the atmosphere, loss of biodiversity.

Figure 1. Sustainability Hub island

In the section “Georesources and circular economy” (section 3) the concept of resource is emphasized, highlighting how waste can also become a resource for the production of secondary raw materials. The role of the circular economy in production processes is introduced.

The “Sustainability Indicators” section (section 4) shows the concepts and definitions of “Water Footprint”, “Carbon Footprint”, “Ecological Footprint” and “Ecological Backpack” through interactive examples, practical activities, internal and external resources. In this section pupils can also calculate the various indicators related to their daily actions such as washing, drinking, eating or using the smartphone.

The "Agenda 2030" section (section 5) focuses on the most important international meetings and agreements leading to the 2030 Agenda in 2015. All the 17 SDGs and 169 targets are described, defining the three dimensions of Sustainability (economic, environmental and social) and the “5 P” pillars: Planet, People, Prosperity, Peace, Partnership.

The "Sustainable City Game" (section 6) is an interactive game similar to the “Game of the Goose”. Each avatar becomes the pawn and the champion of one SDG. Dice have an octahedral shape and represent 16 objectives of the Agenda 2030. The interactive game boxes are an ideal route from a conventional city to a sustainable city. To reach this target, players must face different tasks: individual multiple choice disciplinary tests, online games, digital draws, multiplayer challenges.

At the end of the activity satisfaction questionnaires were proposed, composed both by a series of statements to rank with Likert scale (1: strongly disagree, to 5: strongly agree) and by open-answer questions. The questions concerned the consistency of the educational path with the sustainability topics, clarity and completeness of in-world and web-resources, niceness of learning scenario, and the effectiveness of practical activities. Most teachers' answers (more than 70%) are encompassed in the range of 4-5 Likert scale (Tab. 1). The open-answer questions allow the authors to collect suggestions for improving some areas of the island. A certain difficulty in moving across the virtual island and in managing the various functions of the viewer emerged by teachers' answers. Therefore, for the following experimentations the time for teachers' training will be extended.

Table.1. Satisfaction questionnaires answers.

Questions	**Likert scale**		
According to Likert scale (1: strongly disagree, to 5: strongly agree).	**% 1-2**	**% 3**	**% 4-5**
The educational pathway is consistent with the sustainability topics	0.0	23.8	76.2
The multimedia presentations and info-panels are clear and explanatory	0.0	28.6	71.4
Web resources and on-line games are suitable for learning	0.0	28.6	71.4
The learning scenario is engaging	0.0	23.8	76.2
The number of practical activities is enough to foster learning	19,0	0.0	81,0
Practical activities are well-structured	0.0	42,9	57,1
Moving through the different part of the island is easy	9.5	38.1	52.4

DISCUSSION AND CONCLUSIONs

Some points of interest were observed during the experimentation and others were evidenced thanks to the data evaluation. Based on teachers' opinion, Sustainability Hub is an educational tool well-organised and effective to approach Sustainability topics. The didactic activities, the in-word and online educational resources are involving and consistent with the aims stressed in Goal 4.7 of Agenda 2030: "by 2030, ensure that all learners acquire the knowledge and skills needed to promote sustainable development" (UN, 2015). Furthermore, the use of Geosciences topics like water, carbon and ecological footprint and overexploitation of geomaterials allows students to acquire new knowledge and competences about Sustainability, with its many interdisciplinary connections. Sustainability Hub offers also the possibility to reflect about simple but effective actions to take in everyday life to increase sustainable awareness, to promote pupils become active change-makers and promoters of a new environmentally-friendly culture.

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4.6.2 Sustainability Hub- Experimentation with students

The following paper, entitled "*Teaching sustainability and Agenda 2030 topics in virtual worlds",* was presented at the conference EDULEARN 2021.

TEACHING SUSTAINABILITY AND AGENDA 2030 TOPICS IN VIRTUAL WORLDS

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[1]*University of Camerino (ITALY)*

Abstract

This work focuses on an Opensimulator-based virtual island dedicated to sustainability topics and Agenda 2030 goals, called Sustainability Hub. Teachers and students can access the island as avatars and interact with objects and other avatars. This educational activity was experimented with K7-K8 students, who accessed the Sustainability Hub from their home during COVID-19 lockdown. After an initial training to master how to move and act in the world, students were free to explore the educational paths for 2 hours and were involved in various tasks. At the end of the experimentation, both satisfaction questionnaire and final test were administered to students to verify the acquisition of new knowledge and skills regarding the sustainability topics, and to check their level of engagement in the activities. Results show high degree of interest and participation among pupils. In addition, the final test shows better scores for the experimental group with respect to the control group who explored the Sustainability Hub solely in screen-sharing mode, testifying the educational validity of this activity.

Keywords: Sustainability, Virtual Worlds, Opensimulator.

1 INTRODUCTION

According to the 4.7 target of the United Nation Agenda 2030, education is one of the crucial keys to drive the social transformation towards sustainability [1]. Moreover, digital literacy is an important skill of the XXI century and can be an engaging tool to address topics dealing with sustainability among students [2].

Due to the COVID-19 pandemic, schools facing distance learning struggle with preserving human interactions among the school community. The use of virtual environments can partially overcome this issue, allowing teachers to set up synchronous collaborative activities and group communication with a sense of presence [3]. The rising need of such virtual environments gives a good opportunity for the development of different topics regarding sustainability and Agenda 2030, of particular interest for the teachers of students in these age range. Virtual worlds bring students beyond the wall of the classroom in an environment closer to videogames, very familiar to them [4], where they can collaborate and interact [5].

In literature, there are few cases of worlds devoted to Sustainability using Second life platform or its opensource counterpart Opensimulator. As an example, in Secondlife, Etopia Island was used by university students to follow an educational path on sustainability, particularly on renewable energy [6].

This experimentation has been carried out in Techland, a virtual world focused on math and science subjects for K6-K10 students owned and managed since 2011 by one of the authors. It is powered by the 3D Opensimulator platform and consists of an archipelago of thematic islands [7]. Recently, a new section devoted to sustainability and Agenda 2030 has been added [8].

Figure 1. Overview of Sustainability Hub island.

Sustainability Hub island is the starting point of this section, involving different educational paths, hosted in other connected islands such as waste management, urban sustainability, water resources and so on. In addition, a section devoted to the planet Earth dynamics, developed by A. Boniello is the support to understand the Earth systems as a whole [9].

2 METHODOLOGY

Sustainability Hub is structured in a Welcome Area and five educational sections. These sections are respectively focused on actual global issues, georesources and circular economy, sustainability indicators, the Agenda 2030 goals, the Sustainable City Game. Students/avatars can reach each area both sequentially and randomly.

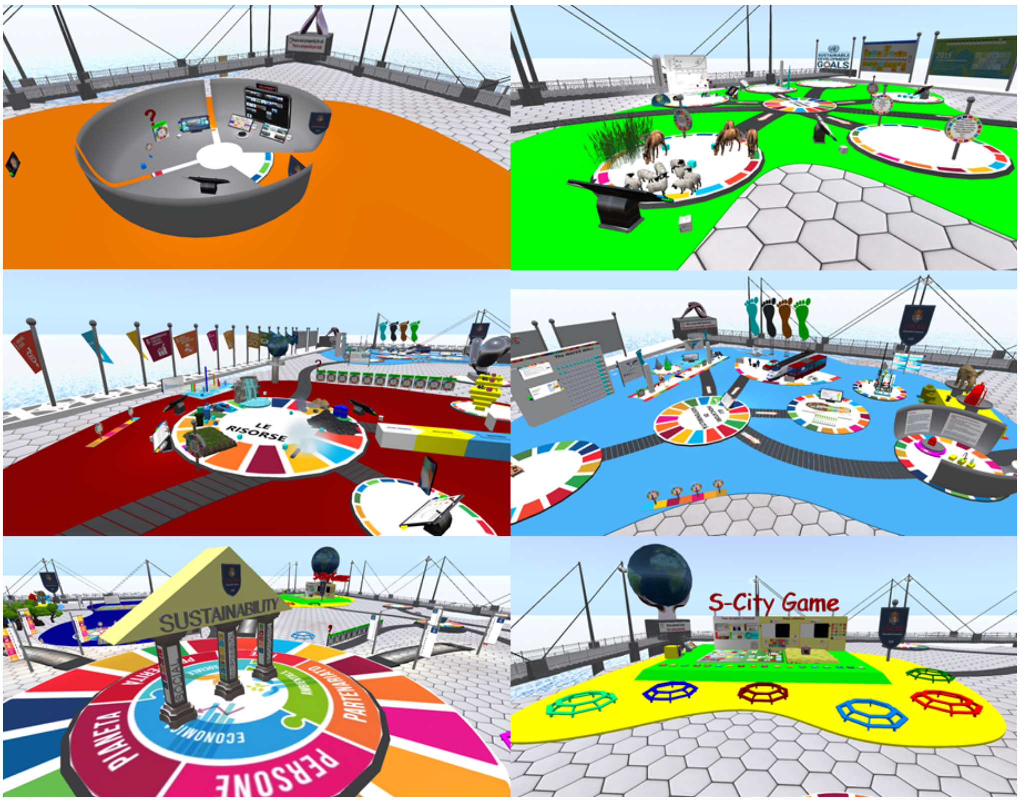

Figure 2. Thematic sections of Sustainability Hub. Top to bottom and left to right: the "Welcome Area", the "Actual Scenario section, the "Georesources and circular economy" section, the "Sustainability Indicators" section, the "Agenda 2030" section, the "Sustainable City Game" section.

In each section there are preliminary questions to engage students and stimulate their curiosity, multimedia presentations, links to external resources, online games, and practical activities for students. At the end of each section, to verify the acquisition of pupils' new competencies, there are interactive quizzes where the children acquire badges if they pass.

This study was accomplished in the first four months of 2021, during a lockdown phase due to the COVID-19 pandemic, when many Italian schools were organized in distance learning mode. The experimentation took place involving K7-K8 students, of which 51 students were in the control group and 36 students in the experimental group, from two different schools. Before this phase, a preliminary study aimed at 21 teachers of various disciplines of primary, middle and high school, was accomplished, to verify the interest of the teachers for this type of educational activity and to improve the hub following also their suggestions. Based on teachers' opinion, Sustainability Hub is an effective educational tool to approach Sustainability topics [10].

In a third meeting of two hours, students were involved in the "Sustainability City Game", a sort of the "game of the Goose" whose objective is to make students reflect on Agenda 2030 topics and urban sustainability. The game was formerly developed and experimented by one of the authors, A. Beccaceci, as a carboard game. Then, a virtual version was developed where the avatars are the pawns of the game [11].

The control group was involved in the same topics but only sharing the screen remotely activities both from home and from school, depending on the regional restrictions. This group approached the Sustainability Hub island as a participating lesson with the mediation of the researcher avatar, acting as a sort of teacher assistant, moving across the island and interacting with different 3D learning objects. During the two-hours participating lesson students were also encouraged to solve online games about sustainability and to challenge quizzes related to the various parts of the island. The aim was to make the lesson more interactive and engaging respect to a simple lecture.

3 RESULTS

At the end of the experimentation, both satisfaction questionnaire and final test were administered to students to verify the acquisition of new skills regarding the sustainability topics, and their level of engagement in the activities. Results show high degree of interest and participation among pupils. Regarding the final test, delivered by an online form, emerge that the experimental group got better score (about 30% higher) than the control group who explored the Sustainability Hub solely in screen-sharing mode, testifying the educational validity of this activity. This result is even more striking thinking that the control group was not following a traditional transmissive lesson, but was actually involved in the activity, therefore it can be expected that a comparison between the experimental and a normal lesson on the same topics would demonstrate even larger differences, as evidenced in other studies [12], [13], [14].

In addition, in two hours of activity, the students of the experimental group acquired 66,7% of the quiz badges available and 38,9% of the students completed all quizzes (fig. 3), testifying that they were involved positively in the activity with a good level of attention to the contents.

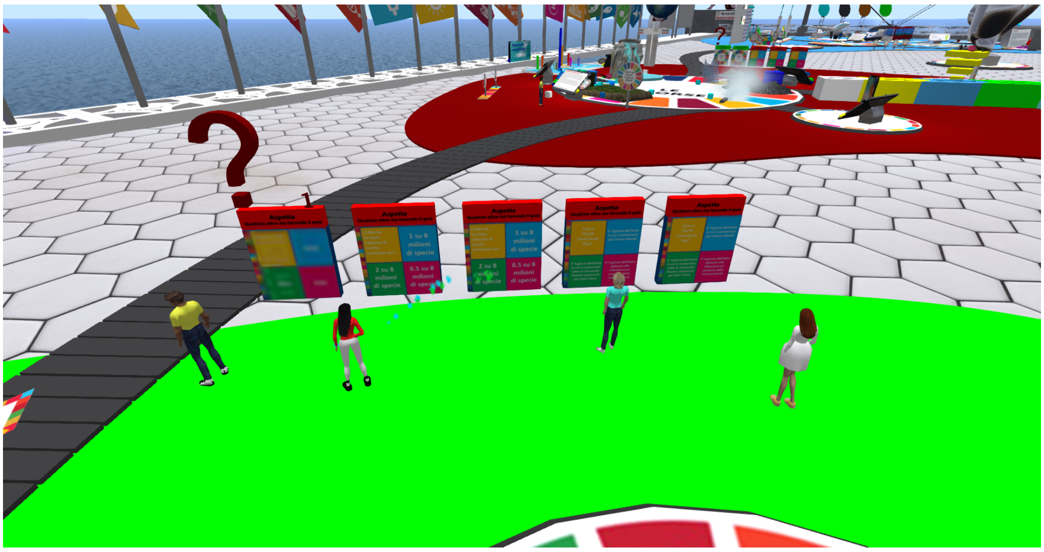

Figure 3. Students challenging with badge quizzes.

The authors also noticed how the experimental group reached a much better environmental awareness compared to the control group, for example reflecting in a higher perception of how soil, rocks and minerals are actually natural resources (fig. 4). Also, the students were exposed to the idea that waste can be recycled and can even considered as a valuable resource, introducing them to the concept of circular economy and other topics linked to the Agenda 2030 which were proposed during the path, like water consumption and saving.

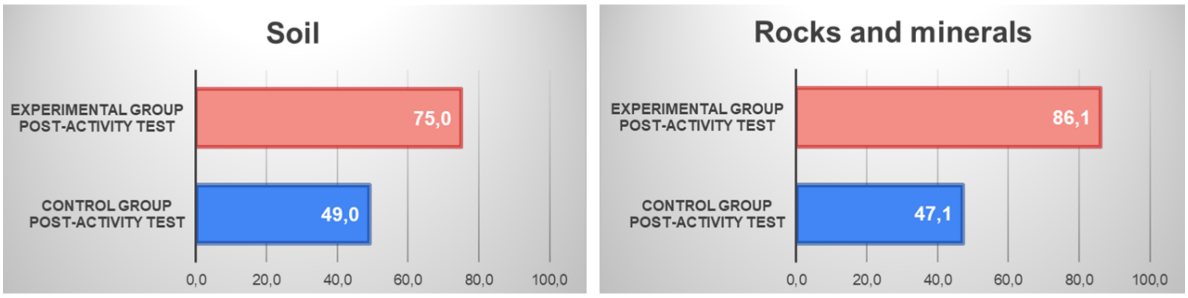

Figure 4. Perception of soil, rocks and minerals as resources (%).

The satisfaction questionnaires proposed consisted of a series of statements to rank using a Likert scale (1: Not at all satisfied, to 5: extremely satisfied) as well as open-answer questions.

As displayed in fig. 5, students appreciated the educational items presented in the Sustainability Hub (green rows in the graph represent very or extremely satisfied values), although it emerged that some items as footprint calculators and external web resources were not tested by a consistent number of pupils due to lack of time respect to the high number of activities to do.

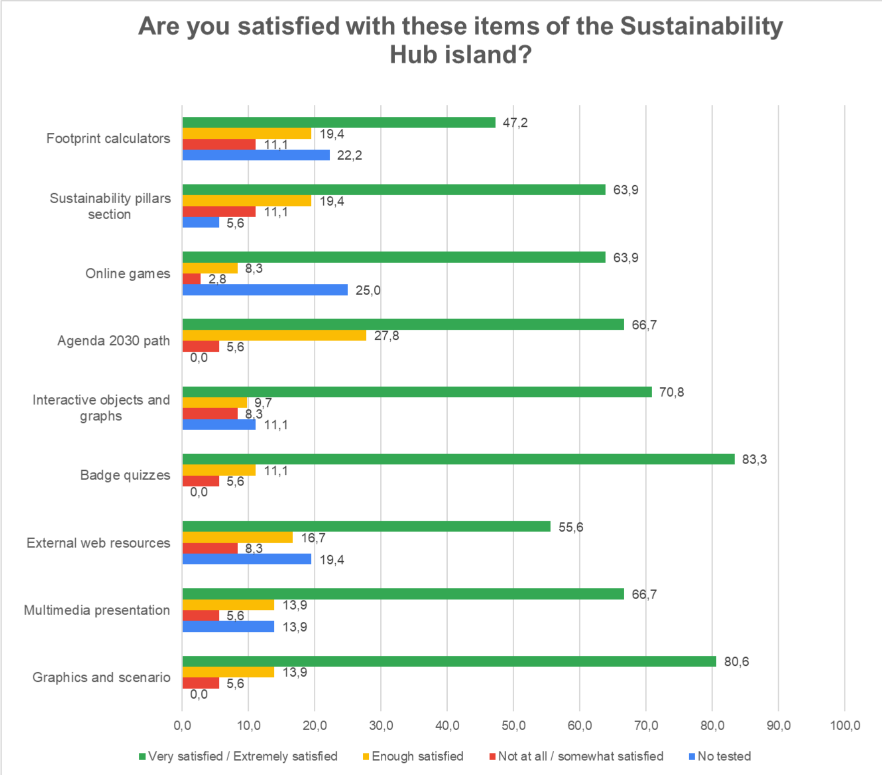

Figure 5. Satisfaction of the various items of Sustainability Hub (36 answers, results as %).

4 CONCLUSIONS

Thanks to the systematic observation of student behaviour during the activity, data evaluation of final tests as well as satisfaction questionnaires emerge that virtual worlds can be an interesting tool to teach sustainability topics. Students appreciated all the activities proposed in the island and the difference between experimental and control group is very appreciable.

However, some criticism emerged: for example, the time required for completing all the activity, which was rich in internal and external resources proposed to the students for the various topics. They certainly need more time to be explored. Other issues were instead of a technical nature, in particular internet connection and computer requirements which, since the students were at home, were not always good enough to fully enjoy the experience.

The next step of this activity will imply to experiment the educational path at larger scale, optimizing the time dedicated to it, but also taking into consideration other suggestions obtained by both students and teachers which are participating in this period, while writing this paper (may 2021).

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4.7. Results about the evolution of Sustainable Development and responsible consumption definition

Thanks to **Activity A** and **Activity B** experimentation, the evolution in pupils' definition of Sustainable development and responsible consumption was tested. Tab. 4.7 and Tab. 4.8, presented and described in paragraph 3.2, are here again reported. They analyze the different levels of achievement related to pupils' definitions of Sustainable Development and responsible consumption.

LEVEL	Description
LEVEL A (elaborated)	The student gives the completely correct definition of Sustainable Development, considering all its pillars (environmental, social and economic). There is the action component in the definition. Specific and elaborated language.
LEVEL B (intermediate)	The student gives a quite correct definition of Sustainable Development, considering at least two pillars of it. There is the action component in the definition. Specific language.
LEVEL C (essential)	The student uses some practical examples of daily routine to explain the concept of Sustainable Development. Simplified language.
LEVEL D (missing)	The student doesn't give any answer/ gives a completely incorrect answer. Very generic and banal language.

Tab. 4.7. Evaluation rubric, specific for the open-ended question about the definition of SD.

LEVEL	Description
LEVEL A (elaborated)	The student gives the completely correct definition of responsible consumption, considering multiple aspects of it. There is the action component in the definition. Specific and elaborated language.
LEVEL B (intermediate)	The student gives a quite correct definition of responsible consumption, considering at least one or two aspects of it. There is the action component in the definition. Specific language.
LEVEL C (essential)	The student uses some practical examples of daily routine to explain the concept of responsible consumption. Simplified language.
LEVEL D (missing)	The student doesn't give any answer/ gives a completely incorrect answer. Very generic and banal language.

Tab. 4.8. Evaluation rubric, specific for the open-ended question about the definition of responsible consumption.

Fig. 4.13 and Fig. 4.14 show that, before the trials, there were many Missing and Essential answers. The significant amount of Missing level answers, before the activity, testifies the very little diffusion of the Sustainable Development topics, suggesting also that is not addressed both in school and in the family or social environment. As expected, in the questionnaires proposed after the activity, there was an improvement in the answers' correctness and in the general quality of the answers given. The answers referring to Missing level of performance decreased, and there was an overall shift towards the upper levels. Nevertheless, there are no Elaborated level answers after the activities. This result testifies that SD is such a complex and multifaceted concept, that the road towards a better pupils' awareness in this issue is long and hard, needing several didactic interdisciplinary paths, throughout the school year.

As an example, one Intermediate level answer and an Essential one, respectively, are reported here: "*Lo sviluppo sostenibile è uno sviluppo per salvaguardare l'ambiente e vuole raggiungere la pace nel mondo; lo sviluppo sostenibile protegge l'ambiente*". On one side, the first definition is more complete, because it takes into account the environmental and social dimensions, on the other side the second answer refers to only the environmental one. More in detail, Activity A allowed a growth of Elaborated answers percentage, more visible than in Activity B.

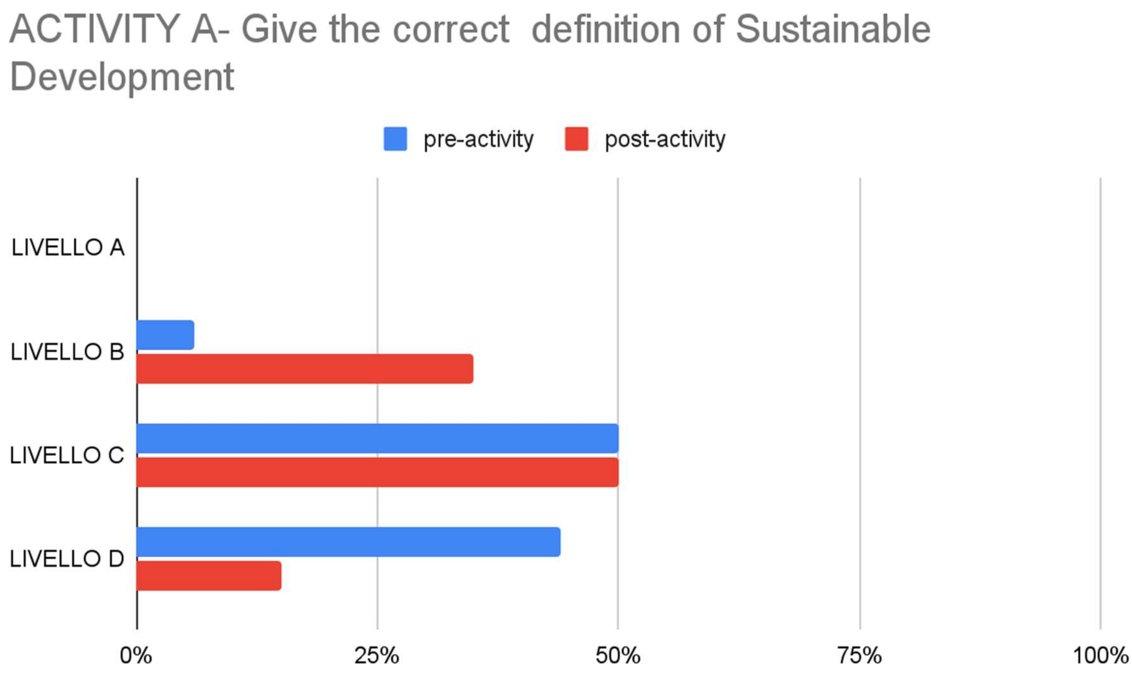

Fig. 4.13. Evaluation of pupils' definition of Sustainable Development-Activity A

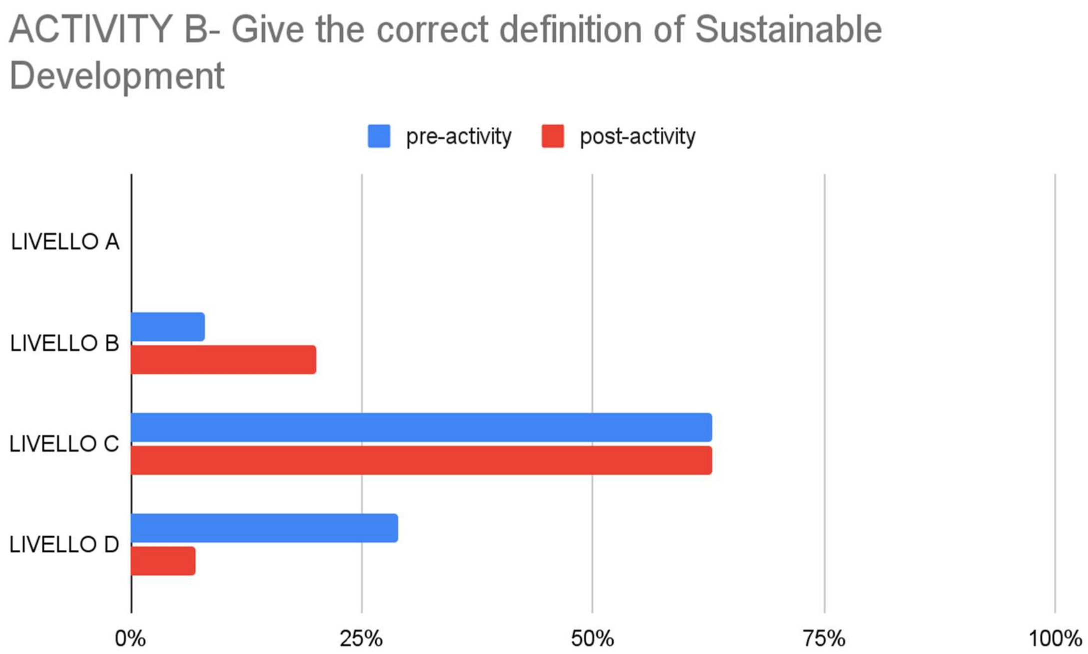

Fig. 4.14. Evaluation of pupils' definition of Sustainable Development-Activity B

Pupils showed a better performance regarding the evolution of responsible consumption definition (Fig. 4.15 and Fig. 4.16). In fact, both for Activity A and for Activity B, Missing answers decreased, while there was a clear increase of Intermediate answers and some Elaborated ones appeared. This could be explained with the fact that responsible consumption is a concept very close to everyday life actions and daily routine. Therefore, students of this age could explain some aspects of eco-friendly consumption behaviors more easily than giving a complete and correct definition of Sustainable Development in its complexity.

An example of Elaborated answer of responsible consumption definition follows: "*il consumo responsabile è un consumo che tiene conto della necessità di salvaguardare l'ambiente e di conservare le risorse del pianeta in modo equo, per tutti*".

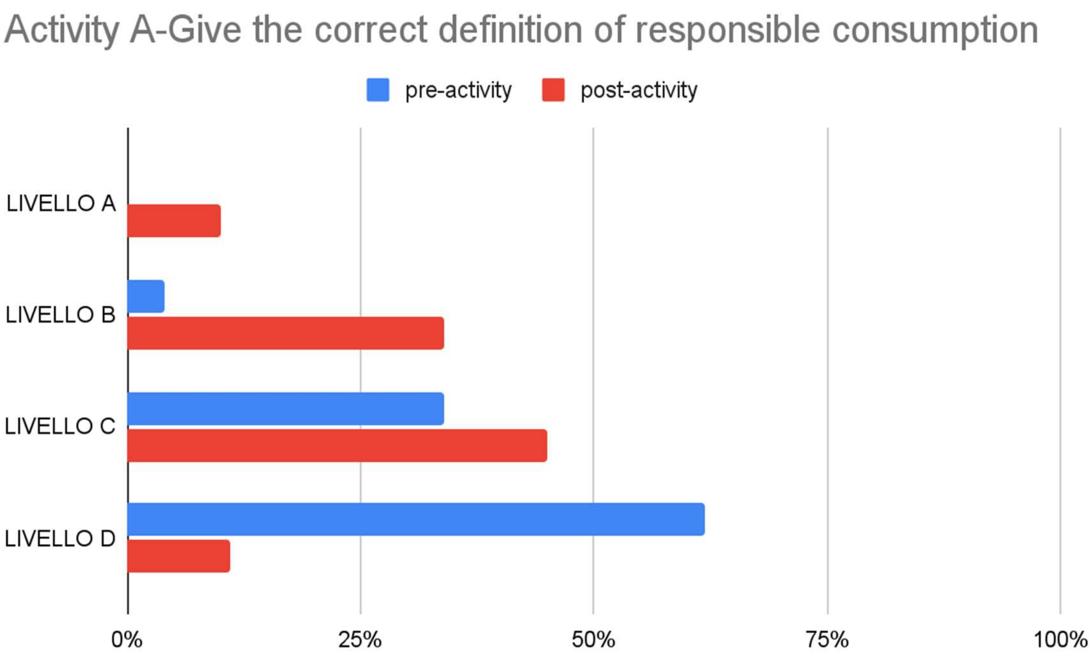

Fig. 4.15. Evaluation of pupils' definition of Responsible Consumption-Activity A

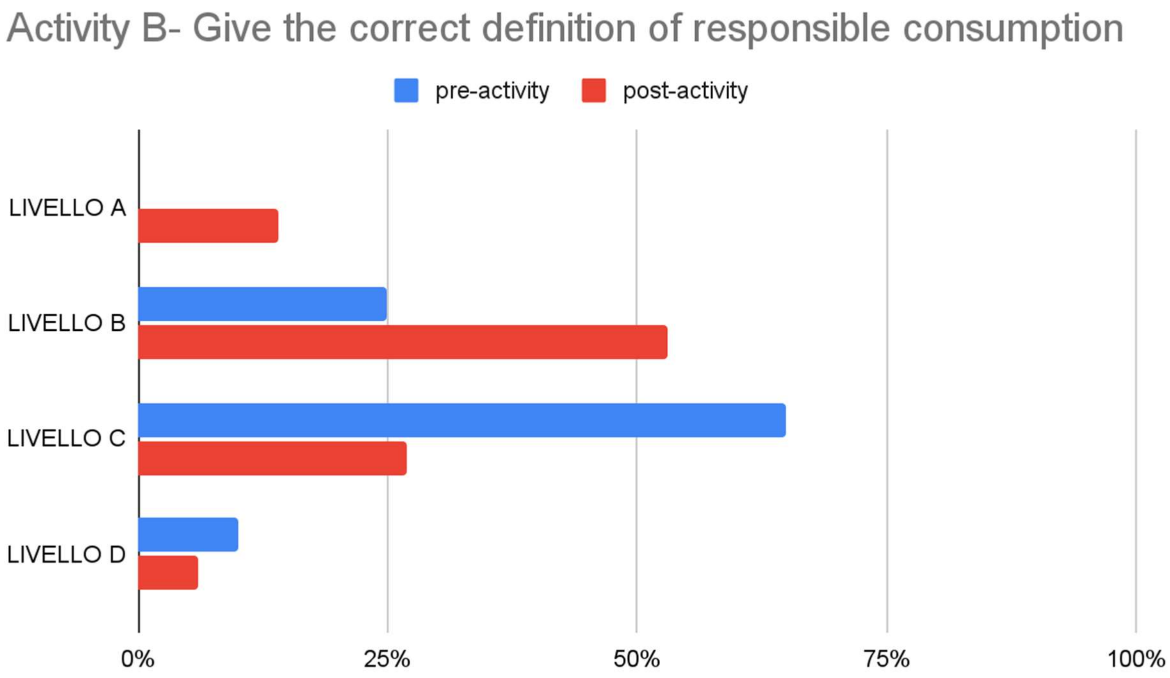

Fig. 4.16. Evaluation of pupils' definition of Responsible Consumption-Activity B

5 - DISCUSSION

This chapter is devoted to a discussion and reflection about the themes touched during the PhD project experimentation carried out both in presence and in distance learning. Discussion and considerations regarding the specific didactic activities tested with teachers and students are reported in Chapter 4, in the papers included. Here, therefore, some general considerations will be discussed and a focus will be put on distance learning problems and opportunities.

The core of this research project in Didactic of Geosciences are Sustainable Development (SD) topics, deeply interdisciplinar and multidimensional, thanks to the several connections with many disciplines, both scientific (Science, Technology, Math) and humanistic (History, Geography, Citizenship). This transdisciplinary feature is very important in education, especially for Middle School where didactic projects are often specific only for a single subject. On the contrary, Education for Sustainable Development (ESD) is cross-disciplinary for its own nature.

At the beginning of my PhD, when I was planning my research, I realized that there was a lack of studies and experimentations in the literature about Education for Sustainable Development and nothing addressed to k6-k8 students. In fact, there were some papers dealing with Education for Sustainability in an interdisciplinary manner, but referring only to high-schools and Universities curricula (e.g.Annan-Diab, 2017; Collins, 2018; Sahakian, 2018). Moreover, the key-role of Geoscience education in teaching Sustainability was not stressed by any publications, until more recently, when few articles started to be discussed this aspect (e.g.Vasconcelos, 2021).

Even today, literature is rich in publications about the theoretical framework of Education for Sustainability, highlighting its fundamental role in achieving a social transformation process (e.g. Tillbury, 1995; Gayford, 1991; Wamsler, 2020).

More in detail, many papers and reviews discuss how Education for Sustainable Development should be integrated and implemented in school and universities curricula (e.g. Zguir, 2021; Williams, 2017). Moreover, several authors (e.g. Ferreira, 2006; Raivio, 2011) also stress the need for a change in education perspective to address Sustainability: hands-on, holistic and active learning approaches based on problem-solving and experiential training, should be well established approaches (e.g. Sharma, 2016; Hedden, 2017). Stables (2002) and Ohman (2005) identified ESD' three essential aspects of holism: connecting the environmental, social, and economic dimensions of Sustainable Development (SD) issues; integrating their past, present, and future implications; and focusing on their local, regional, and global nature. In its core, such an approach aims to nurture wholeness in all aspects of traditionally segmented and compartmentalized educational discourses like those of individual development, relationships between the individual and the world, disciplines of knowledge, educational aims and so on (Pipere, 2015). After holism, the second essential feature of ESD deals with the processes of teaching and learning. ESD focuses on the development of skills and action competence for sustainability; this pedagogy has been labelled pluralism. Pluralistic ESD requires learner-centred and interactive teaching strategies, for example, critical thinking, participatory decision-making, value-based learning, and multi-method approaches, all of which to some degree contrast traditional lecture-based teaching practices (e.g. Ohman, 2004; Corney, 2006; Corney and Reid, 2007; Winter and Firth, 2007; Firth and Winter, 2007; Rudsberg and Ohman, 2010).

Mogensen and Schnack (2010) and Bentham (2013) further emphasize that a key role of ESD in an action competence approach is to develop students' ability, motivation, and desire to play an active role in finding democratic solutions to SD problems and issues. In this light, the purpose of teaching ESD is to empower and motivate students subjectively to take action for sustainable development.

A revolution is needed, (Raivio, 2011) not only in curricula but first in the mindsets and concepts of people, in order to develop new formal and informal educational institutions and practices from preschool through the university and beyond, to life-long learning. Ohman (2021) also proposes a model that describes and frames sustainability commitment to serve as a critical perspective in Education for Sustainability practices in schools. This model suggests that a sound commitment is situated in the intersection of the intellectual, emotional and practical aspects of sustainability. The moral aspect, emotional involvement and implementation of decision-making in ESD is deeply described in literature (e.g. Kopnina, 2014; Felgendreher, 2018; Garrecht, 2018). Individual and collective decisions are closely related to the possibility of improving humanity's relationship with the planet. Therefore, a shift of consciousness in favour of values, attitudes and behaviours that enable the necessary conditions for change is an absolute must (Rieckmann, 2017).

In the light of above, literature extensively tells the global commitment and deeply discusses around ESD-oriented teaching. Nevertheless, there is very little empirical evidence on how these transformative educational approaches are really applied on a daily basis in the classroom. If on one side, the theoretical framework of ESD is deeply discussed in literature, on the other side case studies of experiential learning and activities about Sustainability topics in Middle Schools are very few. Follows some examples of experiential activities about these topics that are very different from this research for approaches, targets and subjects. In a study carried out with k-6 students, Kopnina (2014) tells that the vignette method was used to evaluate the perception of the relationship between environmental and social issues; through reading and discussion among peers, students were able to critically think about the moral dilemmas inherent in Sustainable Development and distinguish between different values in relation to the environment. Hoang (2016) conducted a study on solid waste management education, especially food waste, in two elementary schools, through questionnaires and workshops. He used a simple game card for dividing different kinds of waste. From the results, it was found that after this environmental education activity, the students were adept with the concepts of organic waste, inorganic waste, and recyclable and reusable waste. Some institutions that deal with education, as Alleanza Nazionale per lo Sviluppo Sostenibile (ASVIS), MIUR, UNICEF and OXFAM have made available on the network didactic kits for ESD. See for example:
https://asvis.it/kit-didattico/
https://www.miur.gov.it/documents/20182/1159614/UNICEF.pdf;
http://www.oxfamedu.it/category/risorse-didattiche/argomento/sdgs/.

However, they are mostly informative materials about the SDGs (their contents and aims) and worksheets for pupils of different ages (especially for elementary school). These sheets can help teachers' work to carry out discussions with pupils about SDGs and what they could personally do, according to the sustainability targets (through engage and guide questions). For each SDG, pupils are called to think about how they can act to achieve the targets, after a brainstorming. The OXFAM kit focuses instead on social issues, such as inequality, poverty and migration. On the contrary, the additional value of this project research is to develop more engineering and orchestrated didactic experiences, with several hands-on activities and reality tasks, as well as educational games.

As mentioned above, at the beginning of my PhD, there was a lack of studies and experimentations in literature about Education for Sustainable Development and no study addressed to k6-k8 students. In addition, during the school year 2018-2019, when the first experimentation of the project was carried out, the Agenda 2030 topics were mostly unknown both by teachers and students. Few teachers (Geography ones) had already discussed the Sustainable Development Goals, but to a general degree, only mentioning the main content of SDGs. The SD issues, such as the five dimensions of Sustainability, circular economy, water, carbon and ecological footprint, were barely known to most students and also educators. Only over the last years (2019-2021), schools became more familiar with Sustainability topics, due especially to the introduction of Agenda 2030 for Sustainable Development, first in environmental education and then in Citizenship Education, as its key-issue. Citizenship Education, in particular, was established by MIUR as mandatory in all school curricula (D.M. N.35 22 June, 2019, MIUR, 2019). According to the new law, Citizenship Education could be addressed both as a distinct subject and as a matter spread in various disciplines. In both ways, interdisciplinarity should be the fundamental didactic approach. The recent COVID-19 pandemic also has awakened public conscience about the delicate balance with nature and the inseparable bond between human health and ecosystems (Cole, 2019).

In the light of the above, the first problem schools have had to deal with was: which teachers of which disciplines must address Sustainability issues, including them in their school curricula? And the second one, maybe the most urgent: how to address these issues? And which didactic activities are useful and effective for this aim?

In order to face these school dilemmas, my research aimed to test if Geoscience didactic activities based on active learning and learning-by-gaming could promote ESD in Middle schools, using an interdisciplinary approach. In fact, all the activities created and tested in this research, starting from Geosciences topics, involve teachers from several matters, encouraging pupils on critical thinking about interconnections among the multiple aspects of Sustainability. Although, during the last two years, literature stresses the key-role of Geosciences in Education for Sustainability, practical examples of didactic training and experiences at schools are few. In Italy, Science teachers, working at different educational levels, are trained in distinct scientific subjects, so it is possible that they possess a limited knowledge in some areas of the Sciences they have to teach. Lacking direct experience in all fields of Sciences, teachers have little confidence with some of them. Therefore, they address disciplines most congenial to one's own knowledge (Artigue, 2012), in order to be able to give the best. The teaching of Geosciences is among the most penalized, as many of the lower secondary school teachers (biologists, mathematicians or physicists) have never attended a university course in Earth sciences. In general, teachers of Science, both in first and second grade secondary schools are predominantly biologists (Realdon et al, 2016; Lancellotti et al. 2016). Therefore, the didactics of Geosciences is very often carried out merely following the textbook, without laboratorial activities (Stroppa, 2015), and with little attention to the social implications of the Geosciences, such as those connected to natural resources exploitation and waste production.

In literature we can find few case studies about Geoscience Education for Sustainability. Some of them discuss national projects addressed to a wide target: e.g. Geoparks have excellent opportunities to assist schools as outdoor classrooms and to be incubators of Sustainable Development and sustainable lifestyles (Catana, 2020; Henriquez, 2017; Silva, 2018); World Heritage Sites, like Falun Mine in Sweden (Hellqvist, 2019). Examples of designing Geoscience courses about Sustainability addressed to University or postgraduate students (e.g. Hariyono, 2018; Jones, 2008) are also enough discussed in literature. On the contrary, there is a lack of case studies about Geoscience teaching for Sustainability. A study carried out by Hale et al. (2017) discusses the results obtained from a training course for teachers, designed to enable future educators to engage in sustainability and science concepts. It is devoted to a Water unit that is explored as a case study of the melding of Sustainability and Geoscience to engage teachers in a more nuanced understanding of science education. A mixed methods evaluation of teachers' opinions and products indicated that the Water unit facilitated the development of new understanding and new ways of thinking about teaching their future students. The didactic approaches suggested by this work are storytelling and hands-on activities (building 3D models, writing a narrative story, drawing a graphic display), in order to organize lessons about water, for k-8 students. Therefore, the methodological approaches are different from those presented in this project, as well as the topic addressed: water cycle, water as a system, environmental and human health related to water use. The water footprint of everyday life actions and good consumptions (one of the main topics of this research) is not described by case studies in literature (from the educational point of view). However, Hale's data show that teachers are satisfied with the interdisciplinary and action-oriented approaches, connection with real life and improvement of pupils' problem-solving skills, as this research results stress too.

Other case studies about Geoscience didactic activities on Sustainability come from UnicamEarth research group. Stacchiotti (2019) carried out didactic activities about georesources, using hands-on and the Inquiry Based Science Education (IBSE) approaches. The Wasteberg activity (belonging to Activity A group: Georesources, waste and footprint), that I tested in collaboration with her, focuses on waste and circular economy. By using a familiar comparison, the objective was to attract the interest of students, increasing their understanding and awareness about non-renewable resources and Sustainable Development, by making them focus on resources consumption and the energy flow behind any productive processes. Pupils, divided in groups, worked following the IBSE approach. The activity was carried out using also interdisciplinary aspects, involving teachers of math, history, geography and technology. As a final outcome, pupils determined the economic and environmental advantages that can be obtained by recycling waste materials. Results showed that starting from what had been detected before the activity (the majority of pupils looked at waste only as something to eliminate), a students' mental change occurred: they realized that packaging is composed of valuable resources and waste might be a resource too. Topics such as ecological footprint and ecological rucksack emerged during this activity and have been deepened, in a second occasion, during the Activity “The daily ecological rucksack”. Thanks to an hands-on approach, pupils discovered that behind the production of goods there is consumption of a large amount of natural resources, like water, soil and minerals, as well as CO_2 production/emission. This activity differs from the “Wasteberg” one, because students are prompted to think and discuss about the environmental impact of their daily behaviors and simple actions and how they can act towards eco-friendly lifestyles. As Stacchiotti (2019) stresses, hands-on activities based on constructivism and team-working can improve pupils' awareness about responsible consumption. Instead of the IBSE approach, in “the daily ecological rucksack” experience, a reality task is used: the computation of the water, carbon and ecological footprint of daily actions. But results are very similar to the Stacchiotti ones: after the activity, pupils' consciousness that waste and recycled objects can be considered as resources improved, making them familiar with the circular economy concept. Moreover, both the activities prove that topics such as responsible consumption, waste production and ecological rucksack (usually completely new for pupils) have been very interesting and engaging.

The project experimentations at school were very useful for teachers who could take inspiration from the Geosciences issues addressed and the laboratorial methodologies used, in order to replicate the same activities or create new ones similar. In the light of the above, in order to organize experiential activities, teachers need some materials to consult, time (several hours) for preparation and a good knowledge of the contents as well as different teaching approaches. When one or more of these factors are lacking, educators find many difficulties. An important aspect is that teachers often haven't available didactic materials ready-to-use for working directly in class and should spend hours of work to prepare them. Therefore, they need didactic well-structured tools for approaching educational pathways, especially if about new and complex topics, like Sustainability. Moreover, such well-structured didactic materials are very difficult to find, particularly for k6-k8 students. As a Maraffi's (2019) investigation highlights, about identification of teachers' need from all level schools, the desire to have innovative user-friendly teaching materials is among the predominant ones. A survey carried out by Lancellotti (2015) on a sample of 354 teachers, stresses that, among the most useful materials for educators, there are hands-on activities and those based on interdisciplinary links.

In the light of these considerations, the present research aims to realize well-structured laboratorial activities about Sustainability, with related ready-to-use tools and detailed plans for organizing them. The poor materials used during team-working of "The daily ecological rucksack" activity, allow pupils to become familiar with terms like water, carbon, soil footprint and environmental impact, applied to everyday life actions and goods. Pupils also learned what is a resource and what is the difference between renewable and non-renewable resources and that waste could become important resources by different processes, like reusing, repairing and recycling. The ready-to-use tools are worksheets (reference and operational ones); cardboards; a game puzzle made of paper and a diorama of a tree, called "the sustainability tree". Pupils were invited to stick on this surface pictures of responsible simple action made by themselves or their families. Therefore, students became more mindful that consumerism has a significant impact on the environment and that consumption is a key issue of a more Sustainable Development, according to Goal 12 of Agenda 2030 (sustainable consumption and production). Furthermore, the activity required pupils to apply mathematician computation capabilities and problem-solving competencies. The students realized also that all the disciplines in school are related to each other and can help explain the evolution of human history. They also realized that human actions can put at risk the environment or even life on Earth.

During the didactic activity B (responsible food consumption) pupils observed, measured, collected and interpreted data, starting from a practical situation on a real topic (reality task). The results corroborate the findings of a great deal of the previous work that suggest the effectiveness of an active learning approach based on an everyday life situation (e.g Sharma, 2016). In fact, during all the activity, pupils demonstrated a high level of concentration, engagement and emotional involvement. The game-challenge, cooperative learning have been catalysts of students' learning and motivation. Pupils worked with enthusiasm and motivation thanks to the eye-catching challenge, a reality-task: to prepare the best menu. They discovered with surprise the strong environmental impact of everyday life behaviors, including eating foods. During the cooperative learning, they discussed a lot about their food consumption habits and the corresponding ecological footprint. Before the activity, students already knew the importance of a Mediterranean and varied diet for human health. The additional value of this experience is the main topics addressed: water, carbon and ecological footprint of foods, especially meat and non-local products. In fact, Science curricula usually include nutrients characteristics and food pyramids, in relation with human well-being and the digestive system of the human body. The innovation of this project is to deal with the impact on Earth of food consumption (considering also the transport and packaging). During the activity, pupils were very impressed, discovering the big amount of natural resources and carbon emissions related to food life cycle assessment. The experimentation was carried out in the presence of Science and Geography class teachers who appreciated the didactic objectives and approaches used, cooperating with enthusiasm. Teachers had the role of facilitators and observators and expressed the desire to deepen the topic, involving other teachers too (Technology and Citizenship Education). After the activity, pupils changed their way of thinking, looking at the food pyramid and healthy diet not only as a tool for achieving human well-being, but also as an individual challenge to save the planet. During and after the team work, students discussed critically among peers about their uncorrect overconsumption of meat rather than fruits and vegetables, as well as packaged products rather than unpackaged ones. Moreover, the didactic approach allowed pupils to address sustainable food consumption in an interdisciplinary manner, starting from Geoscience topics. Data showed a significant improvement in students’ awareness about the ecological footprint of their consumption habits after the activity, especially regarding meat consumption and non local products. Analyzing questionnaire post-activity answers, most pupils linked a healthy diet, biological and rich in local products, cereals, legumes, fruits and vegetables to the safety of the Earth planet. Moreover, data show an improvement in pupils' awareness about what responsible consumption means and its implications in daily routine.

Therefore, summing up, the strengths and unique features of this research project are:

1- Interdisciplinarity for development of sustainability topics such as responsible consumption and sustainable lifestyles;

2- Ready-to-use didactic tools to reply the activities or implement them, usable by teachers from different matters (Science and Math, Geography, Technology, History, Art , Citizenship Education);

3- Laboratories realized with poor materials;

4- Focus on a target (k6-k8 students) poorly debated in literature. This age of pupils is so significant for their growth and own identity that adolescents are called *social newborns*, according to Montessori (1970);

5-Dual cognitive channel, used in this project: practical experiences and reality tasks in presence + digital didactic activities in remote, always based on reality tasks.

Moreover, during my PhD, a series of seminars and workshops for teachers from different parts of Italy have been carried out, in order to widely contribute to the dissemination of the Agenda 2030 issues, among school communities. To cite one event in particular, the Alleanza Italiana per lo Sviluppo Sostenibile (ASVIS) festival was a good occasion to speak and discuss (in virtual mode) the essential contribution that education could give to social Sustainability awareness and eco-friendly lifestyles. Thanks to these meetings, sharing of didactic materials and discussions about interesting and actual contents have been valuable opportunities for teachers to catch new ideas for future educational activities. I also carried out some webinars to introduce the Agenda 2030 and my projects to educators, receiving also interesting feedback. This research project, in addition to planning hands-on activities on Sustainability, aims to apply modern didactic approaches that could engage students as much as possible in actual issues. For this reason, a cardboard game, a game-challenge and a digital game have been realized and tested, in order to evaluate their effectiveness to promote pupils' awareness about Sustainability. Although there is a wide literature on the educational value of gaming (e.g. de Castell, 2011; Van der Aalsvoort, 2014; Prensky 2011) the innovative aspect of this research is the topic (Agenda 2030, Sustainability topics, georesources exploitation), addressed with a learning-by-playing approach. The gaming methodology allows to catch pupils' attention and promote their motivation, with also an emotional involvement. The gaming activities S-City game (cardboard and digital versions) were carried out during my second and third PhD year, respectively. They were first tested with teachers, in order to evaluate their educational effectiveness, highlighting strengths and weaknesses. Analyzing teachers' answers to satisfaction questionnaires, one point of interest emerged is that most of them had already discussed the Agenda 2030 topics with their pupils at least on one occasion, but with a general degree of explanation. This data is very different from what has been verified in teachers' questionnaires administered during the experimentation of Activity A (during my first PhD year). In fact, most teachers had declared to know very little about this topic. This confirms the fact that Sustainability topics and Agenda 2030, in all their dimensions, were mostly unknown among school communities, until the last three years, when a growing interest in studying and deepening these issues occurred (also in relation to Citizenship Education in schools' curricula).

Going back to S-City Game activities experimentation, teachers were investigated about their familiarity with Sustainability topics and teaching practices. The most stated to have addressed Sustainability issues as an in-depth study, talking about an environmental or social problem, such as climate change, poverty, hunger or pollution. Most teachers declared not to have developed lessons completely devoted to Agenda 2030 for Sustainable Development or interdisciplinary projects, shared with colleagues. This data is in agreement with what is highlighted by Stacchiotti (2019) who investigated a sample of Middle School Science and Math teachers about their teaching practices. This study stresses a poor trend to develop environmental topics in teaching Science with little evidence of an interdisciplinary and holistic approach. In fact, only 10% of the total uses environmental education as a starting point to address Science topics; 40% of the educators also declared not to link environmental concerns with other dimensions of real life (especially the economic ones). Regarding the satisfaction level of S-City Game activities (cardboard and digital versions), all teachers stated that they are effective educational tools to vehicle the key principles of Sustainable Development and good practices in everyday life. Therefore, after the activities, all teachers expressed a high interest in the Agenda 2030 Goals topics that they would like to implement with pupils in the future, replicating these games or using the ready-to-use materials. The strengths, weaknesses of S-City Game activities and possible solutions for weaknesses, detected through teachers' satisfaction questionnaires, are summarized in Tab. 5.1. The first part of the table refers to both versions, while the second and the third ones stress other points of interest in relation to a specific version.

Strengths	Weaknesses	Solutions for Weaknesses
-Interdisciplinarity is a positive aspect -Very actual issues are approached using everyday life actions -Pupils' engagement and involvement are very high -Students can improve their problem-solving, team-work and transversal skills -Educational games are a tool to improve social competences (e.g., social rules as respect and good competition) -There are contents to improve critical thinking	-Large teams are difficult to manage (sometimes undisciplined behaviour occurs) -Time is limited for the single teacher (few hours a week in one class) -Additional work to assess students' performance	-Thanks to its character of interdisciplinarity, S-City Game activity should be carried out by teachers of different subjects increasing time and contributions -Teachers should be careful observers, to ensure the game rules are respected. -Ongoing evaluation can be carried out through an observation grid
Additional strengths and weaknesses specifically related to the cardboard version of the game		
-Social interactions, in person -Impossibility to carry out this activity on line -Use the same game's tests and trials, using another approach, e.g. as a quiz game -Possibility to discuss and solve problems in a team working in person -Better communication among team components		
Additional strengths and weaknesses specifically related to the virtual version of the games		
Interactivity Engaging virtual scenario, immersive environment S-City game can be played at a distance	-Sometimes it is difficult to move across the different part of the game, slowing down playtime -Sometimes rules are difficult to apply using the interactive panel, causing the game to slow down	-An extra-time devoted to the teachers' and pupils' training before playing can be organized -The interactive panels are managed by a programming language; therefore players have to respect their turn of the game and to press buttons only if it is necessary. -An extra-time for teachers' and pupils' training can be provided before playing with tutorial of the game

Tab.5.1. Strengths and weaknesses of S-City game in cardboard and digital versions.

In general, teachers and students showed very high enthusiasm and appreciation during both versions' experimentation. According to Stacchiotti (2019) Geosciences' educational experiences, based on active learning, are appreciated by teachers, thanks especially to the high pupils' involvement and engagement, also for those less prone to study or with learning disabilities. Most teachers not only expressed particular appreciation for the topics Agenda 2030, but above all highlighted the high educational value of Geosciences teaching, looking at it under another perspective. In fact, they recognize this discipline as no longer a part of the curriculum to be carried out in a mnemonic way and without an emotional and intellectual involvement, but as a founding nucleus from which to build interdisciplinary didactic pathways, related to environmental education. Moreover, according to Pennesi (2017) the peer-discussion, cooperation in teams, enjoyment and problem-solving prompted by the gaming approach are strengths that emerged from the teachers' points of view. More in detail, Pennesi tested some rule-games about soil and its preservation, collecting satisfaction results from teachers, very similar to those collected by this research. In fact, the major point of strengths in S-City Game activities was the high degree of students' personal involvement. Regarding the S-City Game weaknesses, teachers showed to be skeptical about the time for preparing and carrying out the activities, especially if developed only during their own course. Working alone without the help of an expert or a colleague is another difficulty that emerged. The same result is stressed by other Geoscience PhD research experimentations (e.g Pennesi, 2017; Stacchiotti, 2019) that put in evidence teachers' overthinking about the time for organizing and developing such activities, based on hands-on and team-working, problem solving and discussions among peers. For this reason, one of the major objectives of our studies is to give teachers many ready-to-use tools and detailed schemes of all steps to follow, in order to easily replicate the experience. Moreover, the interdisciplinary approach favored the possibility to share the activities among many teachers of different disciplines, facilitating the work organization. Another teachers' doubt detected from questionnaires answers about S-City Game, is how to conduct pupils' evaluation about the activity. The solution proposed was to carry out, in addition to a final test, an ongoing evaluation through observation grid, based on what the single teacher considers important objectives (e.g. attention and motivation, ability to work in a team, respect of roles, critical thinking…). But, as an additional value of S-City game activities (both cardboard and virtual versions), teachers strongly expressed the desire to have the game available in class as soon as possible, in order to try playing with students.

Still in agreement with Pennesi, we can make two points: laboratorial and gaming activities favor learning, thanks to the active participation and emotional involvement that contribute to the internalization of knowledge (Stefanini, 2010); the activities proposed in this research aim to address issues of Geosciences, making them more interesting and interdisciplinary and therefore also more attractive to those teachers who do not have a geological background (especially biologists or mathematicians) who teach Mathematics and Sciences (Realdon et al. 2016; Boniello, 2016).

In my opinion, thanks to a careful observation of players' behavior, S-City Game is more effective in the cardboard version than in the digital one. In fact, the digital version is a bit penalized for the virtual environment: just because of its attractiveness, students sometimes are more fascinated by the new learning scenario than by the final aim of the game. They tend, in some cases, to give importance and attention to their avatars' physical appearance or to learn how to move and interact with 3D objects, causing the game to slow down. A solution to overcome this issue could be an initial training in the virtual world, in order to allow pupils to already get familiar with the 3D environment. But for this aim, teachers could need extra-time, e.g thanks to an interdisciplinary project that involves other disciplines, such as technology.

Nevertheless, the S-City digital game experimentation results show that teachers give an excellent evaluation to the learning experience, evaluating positively the interdisciplinary approach, the multiplicity of skills and competences involved, the team working and the use of ICT. These results are in agreement with a Maraffi's (2018) study on a computer game project. According to Maraffi (2018), the immersive environment of a digital game and the use of technological tools is one of the most attractive features especially for pupils: they judged it as an effective tool. The interactive features of the activity revealed a greater involvement of all the students, without distinction, involving even the students less prone to study or with Special Educational Needs. These results are particularly important because the professional judgment of the teachers can provide information that can contribute to the improvement of the game. Also, their positive evaluation supports the idea that such an approach could be successful in many schools at different levels since it could meet the interest of both students and teachers.

During all the experimentations, Science and Math, Geography, Technology, History and Citizenship teachers (alternatively) could evaluate the activities' organization, timetable and ready-to-use tools, turning among the team-works and carefully observing students' behaviours. Teachers were satisfied with the activities proposed both for the various topics involving their own disciplines and for the methodological approaches. They welcomed the experts in their classrooms, in order to engage students in something new and different from the traditional lessons and to take suggestions for their future work. Teachers, in fact, could acquire new competencies for replicating the same activity with other classes and for continuing to deeply discuss the same topics with students throughout the school year.

This research project aimed not only to address new topics as Sustainability ones, but also to give students and, especially teachers, interdisciplinary inputs. Using them, educators can pursue working in class, involving also other teachers. Maraffi (2018) highlights the great educational value of didactic pathways based on connections among several disciplines (Geology, Geography, History and Literature), through gamification. A role-playing activity by Acqua (2018) on soil consumption and Stacchiotti's (2019) IBSE activities on georesources, involve different subjects too. The social aspects of these activities made them fit for transdisciplinary insights, successfully involving teachers from both scientific and literary disciplines.

Another point of interest is that this research project contributed to re-evaluate the teaching of Geoscience at school, usually neglected because of the lack of time or the poor preparation of teachers in this discipline. Several Geosciences topics such as climate change, natural resources consumption and preservation, and ecological footprint were addressed, thanks to the Agenda 2030. These issues have been developed in a transdisciplinary manner, using several interconnections among different subjects. For example, the ecological footprint of everyday life actions and of food consumption are topics linked to several issues: social ones (inequality, poverty, hunger, migration); environmental (pollution, climate change, natural resources overconsumption); economic (poverty, goods consumption and production, circular economy). Therefore, a lot of school matters are involved: scientific (mathematician computations, environmental concerns); literacy (geographical distribution of poverty and hunger, migration…); technology (water and carbon footprint. The constructivist approach, based on hands-on activities, team works and serious game activities, characterized all the research experimentations. Students worked in groups, collecting and analyzing data, discussing and solving problems using different competencies from several disciplines, as mathematician competencies. The reality tasks carried out with pupils, (computation of simple daily actions ecological rucksack and of a daily menu ecological footprint) are complex and open problems proposed as a means for students to demonstrate their proficiency in skills (Glatthorn, 1999).

The reality tasks give to the didactic experiences these following additional values:

- pupils can show what they have learned, but above all, generalize and transfer what they know (knowledge) and what they can do (skills) to solve a real problem in a new context (Gentili, 2016);
- to highlight and improve the new competencies pupils acquired in multiple and diversified ways;
- the direct and evident connection with real life engages pupils who are motivated by the challenge the task proposes (Gentili, 2016);
- to improve pupils' metacognition and divergent thinking in all phases of the activity.

With a specific regard to the activities developed in this research, the reality tasks aim to improve several competences, as mathematicians and statisticians, in addition to the scientific ones.

Considering the new economy, Information and Communications Technology (ICT), the different online applications – especially social media – represent a completely different and new structure in communication and education (Hegyes, 2017). Society is entering into an era where the future essentially will be determined by people's ability to wisely use knowledge, a precious global resource that is the embodiment of human intellectual capital and technology" (Mupa, 2011). According to Hegyes (2017), in this new knowledge-based economy, education has a continuously increasing role in knowledge transfer – with use of the different types of Information and Communications Technologies (ICT) knowledge can be more easily identified, captured, organized, created, learnt and disseminated. According to the reports published by the European Commission (2017), in 2016, 44% of the European population had an insufficient level of digital skills. 19% had none at all, as they did not use the internet – there is a little improvement in comparison with 2012, when this rate was 23%. There are large disparities across countries, with the share of people without digital skills ranging from 3% in Luxembourg to 41% in Bulgaria and Romania. In Italy at least one-quarter of the population had no digital skills in 2016. The distribution of digital skills in European countries' populations (2016) are shown in Fig. 5.3, while students' confidence in their operational use of ICT (Likert scale from 1 to 4 points) is shown in Fig.5.4 (European Commission, 2013). Therefore, teachers are responsible for development of digital literacy, digital competence, responsible and safe Internet usage and also for acquisition of the virtual space capabilities at all levels in education.

As deeply discussed in Chapter 1, although the relationship between education and Sustainable Development is complex, there is no doubt that education is an essential tool for achieving Sustainability. Also the United Nations highlighted the importance of Sustainability and the role of education and digitalization in it. The 2015 UN General Assembly emphasized the cross-cutting contribution of ICT to the newly defined Sustainable Development Goals and as ICT can accelerate the progress of Sustainability. For all these reasons, in addition to COVID-19 pandemic crisis and forced distance learning, one of the main objectives of the present research is the improvement of pupils' digital skills, through didactic experiences in a virtual world. The S-City digital game activity allows us to satisfy two needings: students' digital competencies implementations and addressing Sustainability topics in an engaging and original approach.

5.1 Distance learning during COVID-19 pandemic: how to face this issue?

During March of 2020, COVID-19 pandemic crisis suddenly hit all the world, causing serious problems for all society dimensions: public health, economy, sanitation and education. As a consequence, this project research found an opportunity to go on, thanks to the use of digital environments in distance learning.

5. 1.1 Advantages and disadvantages of distance learning

Distance education is defined by Bozkurt (2019) as "any learning activities within formal, informal and non-formal domains that are facilitated by information and communication technologies to lessen distance and to increase interactivity and communication among learners, learning sources and facilitators". It is a learning methodology that is so different from traditional education and consists of studying from home where students and teachers are physically distant and electronic means are used to keep students in touch with teachers, providing access to communication between students and bridge the gap and distribute educational material through distance learning programs. This kind of learning has its own advantages and disadvantages.

Anderson (2011) examined the possibility of building a theory of online education, starting with the assumption that it would be a difficult, and perhaps impossible task. He considered a number of theories and models concluding that the effective learning environments, as also the digital one, are framed within the convergence of four overlapping lenses: community-centeredness, knowledge-centeredness, learner-centeredness, and assessment centeredness. These lenses provided the foundational framework for Anderson's approach to building an online education theory, as he examined in detail the characteristics and facilities that the Internet provides with regards to each of the four lenses. He noted that the Internet had evolved from a text-based environment to one in which all forms of media are supported and readily available. He also accurately commented that the Internet's hyperlink capacity is most compatible with the way human knowledge is stored and accessed. In this regard, he referred to the work of Jonassen (1992) and Shank (1993) who associated hyperlinking with constructivism. The essence of interaction among students, teachers, and content, ensured by distance learning, is well understood and is referenced in many theories of education, especially constructivism (Picciano, 2017).

Literature tells us that there are many positive and negative aspects of distance learning (Sadeghi, 2019; Vlasenko (2014). Among the advantages, regarding school education there are:

- Students can learn from anywhere and at any time. It does not matter in which part of the country they are living in, they can join the lessons and start learning. The didactic e-material on their own computer or other digital tools allow them to take part to the lessons from the comfort of their homes.
- No commute: pupils do not have to commute in crowded buses or local trains or by cars. They need only a computer with an internet connection in their home and they do not have to go out. Commuting is the most difficult part because it is a waste of time, money, and more importantly the energy. Moreover, studying at home means to avoid carbon emissions due to transports.

These two advantages played an essential role during the lockdown situation caused by COVID-19 pandemic crisis. Other strengths of distance learning are:

- The electronic means are used to distribute the learning material, from several sources (youtube video, powerpoint presentation, didactic materials on virtual platforms...). Therefore, digital tools allow pupils to give access to a lot of contents and engaging learning materials.
- Flexibility: students can have access to study resources and tasks during any time of the day. Therefore, they can review and deepen some contents when they want and every time they desire.

- The electronic means keep students in touch with teachers, and provide access to communication between students. Online programs often take advantage of a number of emerging technologies to make keeping in touch and effectively communicating ideas easier and more efficient than ever before and students may find themselves using interactive videos, e-mail, and discussion boards to complete their lessons. This social and emotional aspect was fundamental for students during the period of lockdown imposed. The risk was, infact, that adolescents and young people could suffer a lot from isolation and could fall into depression. So, the role of school and educators was also to ensure Interactions and relationships among pupils.
- With more flexibility comes more responsibility on the part of the learner. Students must learn to work well independently and without the constant guidance and monitoring of an instructor, making distance learning a challenge for those who are not easily self motivated.
- Get more knowledge about digital technologies: pupils can gain more knowledge of computer and Internet skills thanks to the process of distance learning. Digital skills improvement becomes both the consequence of the distance learning process, but also necessary to have access to this.
- Bridge the generational gap about digital tools between young and adults.

Among the disadvantages, we have:

- High chances of distraction: according to Bijeesh (2017), with no faculty around for face-to-face interaction and no classmates who can help with constant reminders about pending assignments, the chances of getting distracted and losing track of deadlines are high. Students need to keep themselves motivated and focused if they want to successfully complete their distance learning course.
- Complicated Technology: students need to invest in a range of equipment including computers, webcam, and stable internet connection. There is absolutely no physical contact between students and instructors as instruction is delivered over the internet. This overdependence on technology is a major drawback to distance learning. In case of any software or hardware malfunction, the class session will come to a standstill, something that can interrupt the learning process. Moreover, the complicated nature of the technology used in distance learning only limits online education to students who are computer and tech savvy.
- No physical Interaction: learners will often be studying alone and so they may feel isolated and miss the social physical interaction that comes with attending a traditional classroom. Moreover, they don't have the chance to practice the

lessons verbally. The lack of physical interaction in the education process may cause many problems, such as a great degree of flaming and isolation (Dyrud, 2000). Brown (2017) held the idea that learning in a brick-and-mortar institution presents students with the opportunity to meet and interact with people from different locations on a personal level. Distance learning only limits students to classes and learning materials that are based online. Though students can interact through chat rooms, discussion boards, emails and/or video conferencing software, the experience cannot be compared to that of a traditional school. Hara and Kling's controversial study (2000) also found that the difficulty and distress experienced by students online might not be adequately understood. Working alone at night caused many complexities and depressing experiences.

- Difficulty staying in contact with instructors: if learners ever have trouble with assignments, or questions about a lecture while in a traditional class it's generally quite simple to talk to the instructor before or after class or schedule meetings online at a different time. When learners are distance learning, however, they are going to have more difficulty getting in touch with their instructor. Though they can send an email, it's definitely not going to get them the immediate response they would get if they were able to sit down with their instructor (Hutt, 2017).

5.1.2 How Italian schools faced distance learning during COVID-19.

In 2020-2021 most world countries faced a crisis due to COVID-19 pandemic, including learning issues. In late March 2020 and March 2021 too, the Government of Italy, as a lot of countries, declared a nationwide lockdown in response to the onset of COVID-19. The pandemic crisis induced school closures and teaching had to embrace distance learning. Therefore, due to the suspension of educational activities in schools, distance learning was planned and activated, as clarified in the document by the Italian National Department for Education (MIUR, 2020). The adoption of remote teaching using digital tools took inspiration from a didactic national plan established in 2008- called National Plan Digital School, accompanying schools and teachers towards a conscious use of technologies in teaching. Within this plan, national projects such as "National Plan Digital School" (MIUR, 2015) and "Plan for Training Teachers 2016-2019" (MIUR,2016), identify the "digital skills and new learning environments" among the priorities for training. The Italian Ministry of Education (MIUR, Nota prot. 388 del 17 marzo 2020) defined distance teaching activities as "a reasoned and guided construction of knowledge through an interaction between teachers and pupils" and through the construction of a "learning environment, also if unusual for the common idea and experience of teaching and learning, to be created, enriched, lived and remodulate from time to time". The Italian Ministry stressed also that distance learning had the role to keep alive among pupils and educators a sense of belonging to a community, fighting the risk of isolation and demotivation. The interactions between teachers and students could be the vehicle to maintain and strengthen relationships, sharing the new challenges and improving resilience behaviours towards an unexpected situation.

Historically, the Italian schools and teachers have usually shown a certain "resistance to change", which has been widely debated, from many points of view. For example, it is well known their widespread lack of confidence towards Information and Communication Technologies (ICT) and mistrust behaviours towards a change or an extension of their own role and competencies (INDIRE, 2020).

The situation caused by the pandemic has introduced an element of destabilization as never happened before. The teachers had to address "forced distance learning", which urgency had removed the dimensions of intentionality and planning, typical of traditional didactics. The "*Istituto Nazionale di Documentazione Innovazione e Ricerca Educativa"* (INDIRE) conducted research about the didactic activities carried out in all levels of Italian schools during distance learning to investigate methodologies, practises, times.

The preliminary report (INDIRE, 2020a) already stressed the predominance of mere frontal lessons in videoconferences, carried out as a sort of "transposition of traditional lessons" in digital mode. Fig. 5.1 shows the didactic methodologies used by a sample survey of 3774 teachers from different level schools, reported by the last INDIRE report (INDIRE, 2020b). We can see that "lessons in videoconference" were the most diffused and pursued didactic approach in each school level, from Primary to Secondary (89.7% for Primary, 96.7% for Middle School and 95.8% for Secondary school).

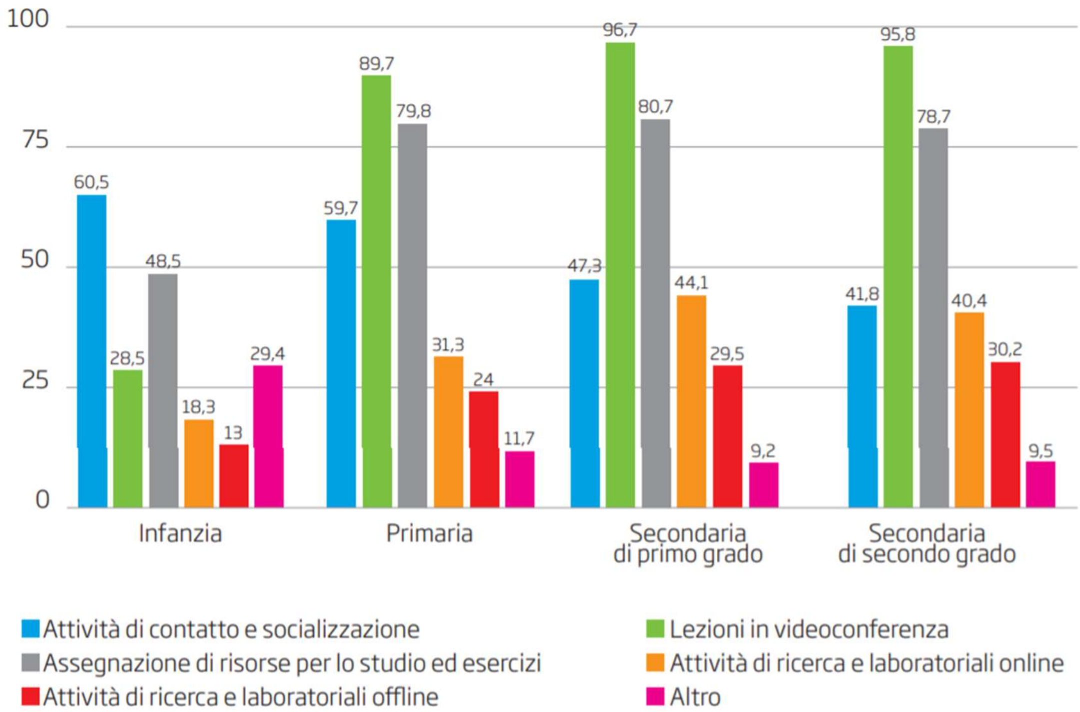

Fig. 5.1. Didactic approaches used by Italian Schools during distance learning (INDIRE, 2020a)

The second more usual didactic activity was "assignment of resources for study and exercises to carry out autonomously" (79,8% for Primary School; 78,7% for Middle School; 80% for Secondary School). The last common component of distance learning is "pupils' evaluation by teachers", carried out by 83% of teachers investigated. On the contrary, the amount of teachers who addressed experiential didactic activities clearly represents the minority, as shown in Fig. 5.2.

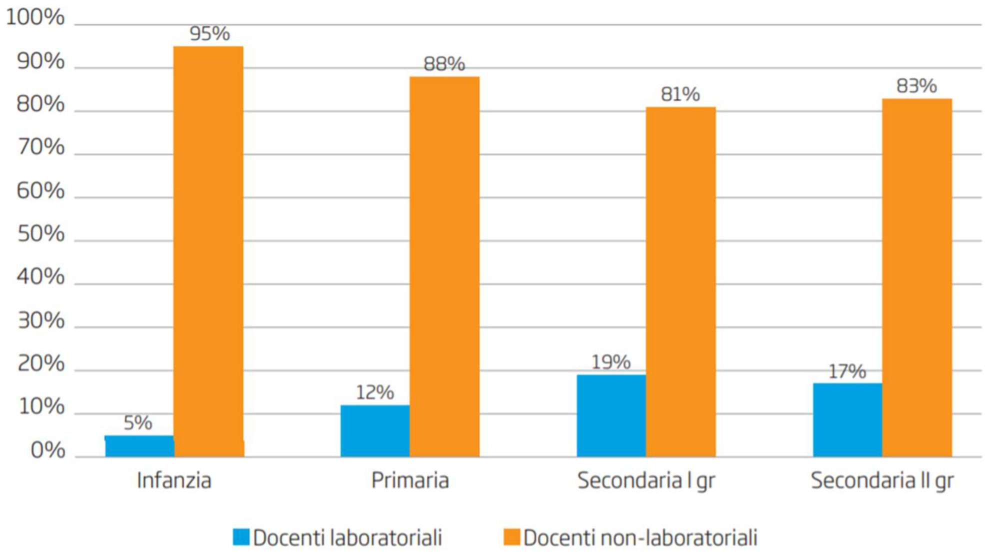

Fig. 5.2. Percentage distribution of laboratorial and not-laboratorial teachers during distance learning. (INDIRE, 2020b)

This group of teachers is called "laboratorial" by INDIRE, in opposition to not-laboratorial ones who carried out only traditional lessons in digital mode. The lessons based on video conferences were the most usual in all level schools. Regarding Middle school, the laboratorial activities carried out through digital tools and environments (online mode) represented 44,1% of the total, more than research and laboratorial activities offline (29,5%), not mediated by virtual tools.

To face distance learning, Italian teachers had to make remote learning effective, engaging and accessible by everyone. In response to this issue, online platforms (e.g. Google Meet, Teams…) were among the first, and easiest, distance solutions rolled out in Italy. However, it is evident that teachers and students found many difficulties in managing digital tools, but especially in adapting their lessons to the virtual channel (Fig.5.3 and Fig. 5.4). A more significant problem has been to carry out lessons in distance learning through, not only a transmissive approach, but also laboratorial and experiential activities

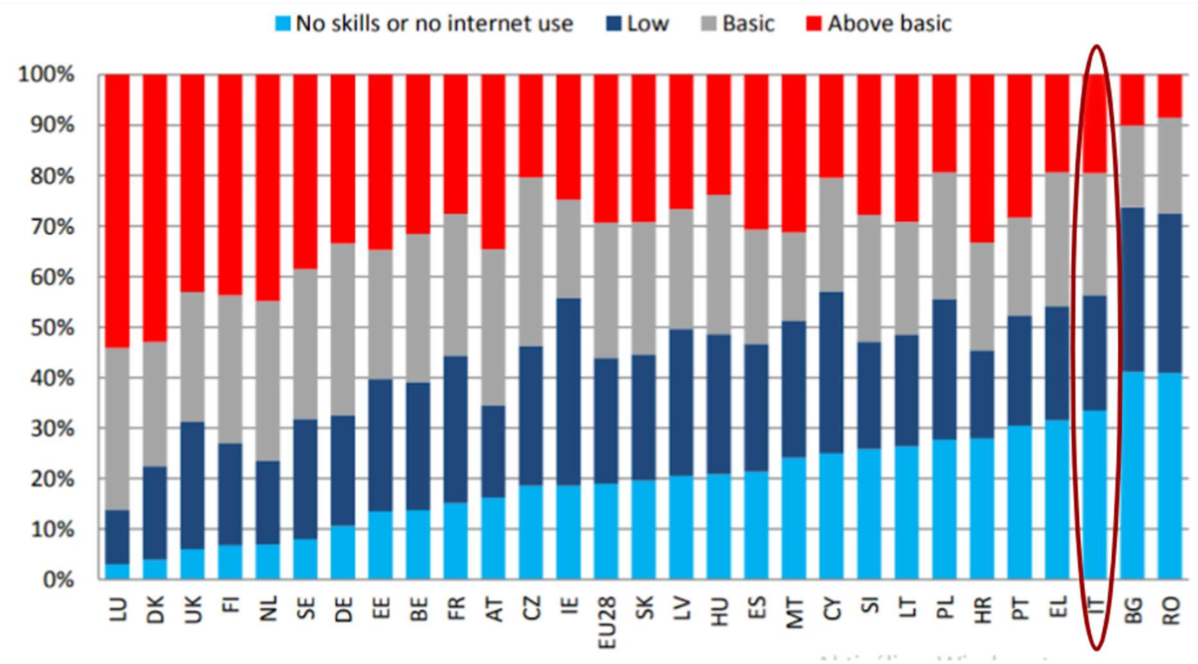

Fig. 5.3. Digital skills of the EU population, 2016. Source: adapted from European Commission (2017).

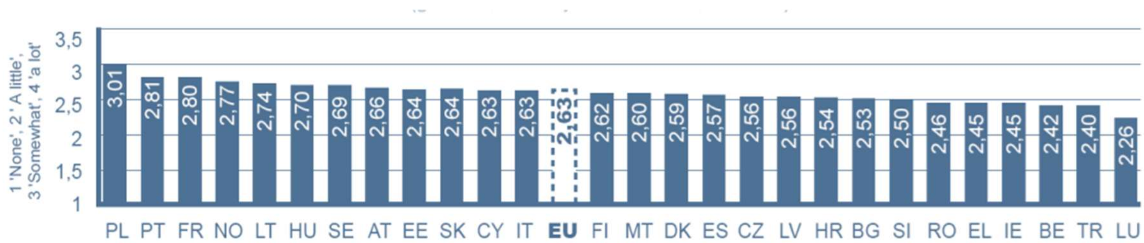

Fig. 5.4. Students' confidence in their operational use of ICT (Likert scale from 1 to 4 points) Source: adapted from European Commission (2013)

5.1.3 How this research project contributed to effective distance learning.

The pandemic crisis caused several problems for continuing this research project:

- the experimentation at school, in presence, was impossible to carry out;
- the didactic activities planned for this project had to be realized in distance learning, assuring, however, pupils' knowledge but also facing the social competencies improvement;
- the didactic activities had to be experiential and based on learning-by-doing, in spite of the distance learning;
- the need to test the activities first with teachers, in order to stress strengths and weaknesses.

In light of these considerations, the collaboration with my colleague Michelina Occhioni allowed us to use a virtual platform for teachers and students, in order to experiment with laboratories about Sustainability topics using the virtual worlds. Thanks to this project, my colleague and I could work with pupils and teachers of schools from different Italian regions during COVID-19 pandemic and lockdown. Therefore, the project became an opportunity for teachers and students to live distance learning in an engaging and funny way.

More in detail, a digital version of the S-City game was developed. This activity is not described in this thesis in detail but only discussed here in view of the comparison with the cardboard game and the possibility to use virtual worlds in laboratory experience. The S-City game was first tested with teachers to verify the effectiveness of the activity and collect strengths and weaknesses impressions. This experimentation showed a high satisfaction degree from educators, therefore the Sustainable City digital game was carried out with pupils. Good results were obtained, both in terms of new content acquisition, improvement of digital skills, pleasure and enjoyment in learning by-gaming, as described in par. 4.5

As a follow-up work, a virtual island called Sustainability Hub was created, always in collaboration with my colleague Michelina Occhioni. S-Hub is a digital environment through which students and teachers could play, interact with 3D objects, learning and study Sustainability topics.

Experimentations with these virtual tools allowed students, as avatars, to enjoy and involve themselves in educational experiences, keeping themselves in touch with teachers and their peers. Moving inside the virtual environment and playing the digital game, pupils/avatars could exchange their ideas, talk by microphone, write through text chat, working groups, overcoming (in part) the sense of isolation due to the COVID lockdown.

Another important evidence was that pupils less prone to study or with learning disabilities or with relationship problems, showed a high involvement, participation obtaining good results in terms of overcoming the quizzes and game tasks. Class teachers were surprised to see such students so interested and motivated in the project. Therefore, they observed that digital activities as those we proposed are effective didactic tools for encouraging learning, for more difficult pupils too, according to Maraffi (2018).

In conclusion, the hands-on and gaming activities successfully tested in this research project to address Sustainability topics, were developed taking into account the 3H: Heart, Head, Hand. They represent the goal that every teacher should aspire to, during the didactic design of activities and contents, aimed at the intellectual, manual and emotional involvement of the pupil (Pennesi, 2017; Acqua 2018). These goals can be achieved thanks to a well-prepared teaching staff that feels a strong motivation in continuously updating the didactic approaches and contents.

6- CONCLUSIONS

6.1 Project outcomes

This research project in Geoscience Education addresses topics related to Agenda 2030 for Sustainable Development and its Goals, chosen for their interdisciplinarity that allows to create several connections among different subjects, a very important didactic aspect in the Italian Middle School.

The educational activities on Sustainability issues allowed to deal with Geoscience topics, usually neglected in the normal didactic planning of sciences, but nowadays fundamental because of their actuality. Therefore, Geosciences topics can help correlate themes such as ecological footprint, circular economy, sustainable development, climate change, use and overconsumption of georesources, which can be addressed by linking them with social and economic issues, like poverty, hunger, conflicts, migration, etc. This wide range of topics to be discussed in school is in line with the five pillars of Sustainability (People, Planet, Prosperity, Peace, Partnership) and the need to approach them in a holistic manner.

Didactic activities based on learning-by-doing, learning-by-playing and cooperative learning have been very suitable for interdisciplinary developments, allowing Geosciences to assume a new and fundamental role. In fact, Geosciences have been useful as a starting point to propose other themes,emphasizing the importance of this discipline for acquiring transversal knowledge and skills. In addition, an essential part of this research was to verify whether and how Geoscience topics can efficiently vehicle knowledge in order to improve environmental but also other skills (e.g. mathematics, social), which can therefore be applied to concrete and topical issues.

The key-topics of this PhD research are:

- the water and ecological footprint of everyday life routine and food;
- the Agenda 2030 for Sustainable Development, especially the intersection among Geosciences and its Goals.

This choice arises from the inclusion of Education for Sustainable Development and especially the Agenda 2030 Goals topic in Citizenship Education. Nowadays, in fact, Citizenship education is a mandatory discipline for all level schools in Italy and

Sustainability is one of its three pillars. The other ones are the Italian constitution and digital citizenship. The last one was also considered in this PhD project, through the realization of the S-City digital game and the planning of Sustainability Hub.

The main aims of the project were:

-to improve students' interest and active participation in addressing Agenda 2030 and Sustainability topics, through engage questions, problematic situations, hands-on activities and gaming;

-to realize interdisciplinary didactic activities on Sustainable Development using experiential learning;

-to verify how pupils can identify and justify relationships between their everyday life actions and the environmental impacts of these actions (such as land and water consumption, CO_2 emissions, global warming, etc.);

- to favorite crirìtical thinking about eco-friendly sustainable daily behaviours;

-to use gaming and distance learning to ensure Sustainability topics dissemination during COVID-19 crisis;

-to ensure social competencies and digital skills improvement in distance learning.

Moreover, the general research question of this work was if educational approaches based on constructivism and serious play could be useful tools to vehiculate Sustainability topics. This aspect is of particular interest due to the lack of didactic activities and their experimentation in the recent literature, and the need to provide materials and tools for the teachers to face the new school requirements about Sustainability. The results show that a multidisciplinary approach based on active learning and learning-by-playing, combined with topics close to pupils' real life and with activities carried out in team working, can disseminate in an efficient way Sustainability topics, improving students' awareness.

Questionnaires allowed to determine knowledge acquisition reached by students during the four activities proposed. The Agenda 2030 Goals, Targets and aims, mostly unknown by students before experimentations, became more familiar to all of them. This result is due to the approaches used, based on hands-on activities that put pupils at the center of their learning process. Moreover, pupils could establish and justify relationships between environmental variables, and therefore, by their nature, complex. Peer tutoring during the group work and the practical activities proposed enhanced the process of learning through a greater active involvement of all students, including those less likely to study "traditional".

Discussion among peers and with teachers, during the team-works and gaming, encouraged pupils' critical thinking about responsible behaviours and consumption. They exchanged their ideas about how they could act towards eco-friendly lifestyles, starting from simple daily actions, like e.g. eating, dressing and washing. The activities proposed gave pupils several suggestions for this aim, making all of them think about possible solutions to be adopted by simple citizens, regarding water and georesources consumption, or CO2 emissions reduction Students proposed some everyday life responsible actions to the others who could take inspiration for future behaviours. These ideas of active change towards sustainable lifestyles emerged during the activities, then became points for discussion with students' friends and families. It is a very important result of this research, because the dissemination of Sustainability topics at school represents a good vehicle to spread these issues in all the community.

The COVID-19 pandemic crisis caused several problems to the continuation of this project, given the impossibility to realize hands-on and laboratorial activities in presence. This difficulty, however, allowed to take another strategy which has proved equally effective. In fact, the cooperation with my colleague Michelina Occhioni allowed me to realize educational activities through virtual environments, maintaining the core idea of an active learning approach.

The experimentation during distance learning, through digital activities, allowed me to test the project in distance mode, obtaining good results in terms of teachers and students involvement and pupils' learning. Teachers could cooperate using unconventional teaching methods and tools, acquiring new competencies that can also be applied in their future work. The S-City digital game and S-Hub activities required teachers to get involved, embracing something new and very different from the traditional didactic, overcoming the digital gap between adult and young people.

The activities presented in this doctoral thesis have shown that some Geoscience topics can be effectively used as a founding core for studying Environmental Education at school, involving other disciplines and teachers. Environmental Education and Education for Sustainability can take inspiration from Geosciences that have a key role in understanding all the relations among different

Earth systems and between humans and our planet. Moreover, the experimentation inspired some teachers to work again with students not only on the same topics proposed, but also on several related subjects. Consequently, the success of the experimentation proves that this research contributed positively to the dissemination of sustainability topics among teachers, and pupils, but also families, who were involved in the projects. School Principals were also directly involved, since often the schools had the chance to carry out projects with other schools in Italy on the same topics, participating also in competitions and calls for grants.

Natural environment and its resources can't be exploited in an unlimited and unconscious way, but it should be considered as a common heritage, worthy of respect and protection. This is indispensable for the planet and humans themselves, whose life depends on Earth's health. The necessary change of mind is an idea of humans as an integral part of the Earth system. Environmental protection is not a gesture of respect, but an essential action for survival. A clear example is the fight against climate change: humanity could not survive for a long time if the atmospheric temperature continues to grow in an uncontrolled way.

Nowadays, Sustainability topics play such a fundamental role in education at all levels, that they should be developed both in single disciplines curriculum and in interdisciplinary projects, involving all matters. Teachers are called to plan didactic pathways, based on interdisciplinary; a close-knit team of educators allows to successfully achieve this goal. They should plan a set of didactic activities aimed at developing the intellectual, moral and physical faculties of individuals, according to the five principles of Sustainability: people, planet, peace, partnership and prosperity. For this aim, Education for Sustainability should not be limited to providing information, raising public awareness and disseminating knowledge, but rather should aim at a correct and forward-looking relationship between human and the environment, changing habits and behaviour, promoting new values; giving criteria and guidelines for solving problems and making decisions.

Education for Sustainability needs a structured, complete and coherent educational framework both in the school environment and outside it and at all levels, from kindergarten to university. This framework should be constantly updated and evolving to be able to face future environmental challenges and enriched with ideas and solutions from all actors of society and education.

6.1 Implications and future work

UnicamEarth, the research group I belong to, is composed of teachers interested in improving their didactic and educational competencies, in terms of both new subjects to study and new approaches and methodologies to apply. Doctoral researchers from UnicamEarth have approached several Geoscience topics for years, with the aim to spread environmental issues among school communities.

In the last few years, Sustainability has become the core topic of study for this group, because of the growing need to form conscious and aware citizens. This research project has taken inspiration from the previous ones on Sustainability, focused on soil and other natural resources responsible consumption. Therefore, it is a work that has its continuity in time, from the past,in collaboration with Lucia Stacchiotti, to the future. In fact, the collaboration with my colleague Michelina Occhioni has allowed me to develop a part of a bigger project dealing with Sustainability in virtual worlds. This project will be finalized and tested in its completeness by my colleague and will be the subject of her doctoral thesis.

Sustainability continues to be the common thread of our research group. A new project is dealing with ocean pollution by plastics (in progress). I participated in the beginning phase, when I carried out with pupils an introductory seminar about Agenda 2030 Goals, in order to link Sustainability topics and SDG14 (life below water) to ocean pollution issues. This and other future research will contribute to educating young students for a transformative process with time, starting from responsible simple daily actions.

The PhD career allowed me also to improve technical competencies, in relation to educational game creation. In fact, a digital educational game design has been developed in

collaboration with a Computer Science student. This game, called EcoPhenix, aimed to improve players abilities and competencies in responsible and eco-friendly behaviours. More in detail, starting from an apocalyptic scenario, where there was nothing except some resources to survive, players have to build tools for housing or providing food (hunting, fishing…). The resources available are the natural ones (soil, water…) and those derivable from waste to reuse or recycle (discarded objects, WEEE…). The unique feature of this digital game is that the final aim of players is not only to survive themselves, but also to make actions as eco-friendly as possible. The game score, in fact, depends mostly on the environmental impact of each action. Since it is a game planned to be played by students (at least k7) and young people, fun and enjoyment are indispensable aspects to be achieved. Therefore, EcoPhenix includes fighting against enemies and other trials to overcome, prizes to win, penalties, as well as the possibility to die and to gain new lives.

This last experience was very useful for me, because enhanced my comprehension on some important features of an educational game planning:

- to ensure *enjoyment and fun*, even if it is a serious game;
- to insert educational contents in an involving and appealing framework;
- to create playing situations that require problem solving skills and call students/players to get involved;
- to realize quizzes, tests, trials that should strongly motivate pupils in giving the best of themselves.

Educational games planning has been a completely new and training professional experience for me and the skills I acquired will be precious in my future work at school. In fact, a longlife learning needs educational activities that remain imprinted in pupils' minds, thanks to their high interest, enthusiasm and excitement. My research experience proved that gaming is an efficient tool for achieving this aim, if well planned and structured. Therefore, my intention is to continue to use the gaming approach especially in dealing with complex and difficult topics, both in Maths and in Science teaching.

At the same time, I would deeply develop Sustainability topics with my future students, in an interdisciplinary way, involving different teachers. In fact, during my PhD career I learned how important is the contribution that education could give to a social transformation process. The UN call for an Education toward Sustainability is now part of my professional background that I will never neglect, as Geosciences topics study, especially those intersecting SDGs (climate change, natural resources, soil and water preservation, waste, circular economy…).

The methodological approaches I used and the activities I carried out will be proposed to my future students and make available to my colleagues. Taking inspiration from these, I will realize new educational pathways, hoping to also have the collaboration of other teachers. The new skills and competencies of my PhD study will be precious tools to address my teacher's job in a more proactive and dynamic way.

The final aim is that pupils' could mirror the teacher's positive attitude, responding promptly to the educational incentives. Maybe more than ever, Italian schools are called to catch students' interest and motivation in learning, considering the difficult historic period due to the persistent COVID-19 pandemic.

Thanks to this project, several collaborations with PhD students, teachers, schools were born, giving a higher major value to this research work and enriching my professional competencies in general.

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CONSUMO DI RISORSE (ACQUA E SUOLO) ED IMPRONTA DEL CARBONIO NELLE AZIONI QUOTIDIANE

-SCHEDA DI RIFERIMENTO-

AZIONE QUOTIDIANA	**IMPRONTA IDRICA (ACQUA)** ***WATER FOOTPRINT***	**IMPRONTA DI SUOLO (TERRENO E RISORSE MINERARIE)** ***SOIL FOOTPRINT***	**IMPRONTA DEL CARBONIO** ***CARBON FOOTPRINT***
BERE 	 ACQUA VISIBILE: in media 2 l di acqua al giorno ACQUA NASCOSTA: ➢ per la produzione di una lattina di bibita gassata (coca-cola, aranciata, estathè) servono 200 l di acqua (soprattutto per la produzione di zucchero contenuto, che è in grande quantità) ➢ per produrre 1 Kg di plastica (PET) delle bottiglie servono 10 l di acqua (1 bottiglia di plastica da 1,5l pesa circa 35g) 	**RISORSE DEL SUOLO NASCOSTE:** ➢ Per produrre una tonnellata di plastica ci vogliono almeno 1,5 tonnellate di petrolio da estrarre dal sottosuolo ➢ Il petrolio serve anche per il trasporto delle materie prime alle fabbriche, dalle fabbriche ai punti vendita e dai negozi a casa. 	**IMPRONTA DI CARBONIO NASCOSTA** Le emissioni di anidride carbonica sono dovute principalmente all'<u>imballaggio e al trasporto</u> delle bottiglie di plastica. ➢ 110 g di CO_2 per mezzo 1 di acqua (80 g solo per la produzione della bottiglia), se distribuita localmente. ➢ O,14 g di CO_2 per mezzo litro di acqua del rubinetto!

LAVARSI

ACQUA VISIBILE:

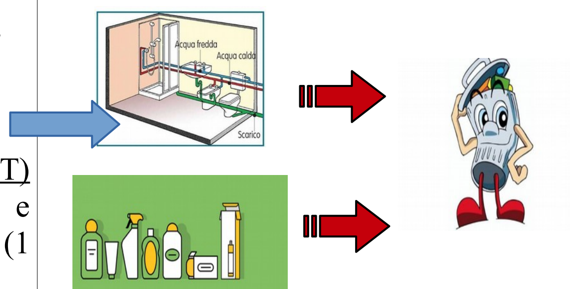
-15 l di acqua <u>per lavarsi mani e volto</u>;
-per fare <u>un bagno in vasca</u> (riempire di acqua la vasca) si consumano circa **130 l** di acqua;
<u>-per una doccia di 5 minuti</u> si consumano **80 l** di acqua ; applicando un frangigetto si arriva a consumare invece 9 l di acqua al minuto per la doccia;
<u>-per tirare lo sciacquone dell' acqua</u> se ne consumano **10 l** ; con i modelli più nuovi a “doppio tasto” quello più grande getta 8 l di acqua, quello minore non più di 3 l alla volta;
<u>-per lavarsi i denti</u>: **6l di acqua al minuto**. Se ci laviamo i denti per 5 minuti lasciando il rubinetto aperto, consumeremo 30 l di acqua, chiudendo il rubinetto il tempo si riduce a 2 minuti

ACQUA NASCOSTA :

-per produrre un <u>tubetto di dentifricio</u> servono **281** l di acqua
-per produrre un sapone da 125 g servono **75 g** (o **ml)** di acqua;
-per produrre <u>1 Kg di plastica (PET)</u> delle bottiglie di shampoo e bagnoschiuma servono **10 l** di acqua (1 flacone da 250 ml pesa circa 30 g)

RISORSE DEL SUOLO NASCOSTE:

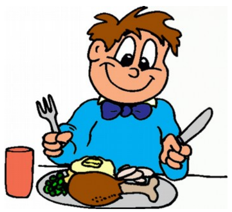
- Per produrre una tonnellata di plastica dei flaconi dei saponi ci vogliono almeno 1,5 tonnellate di petrolio (*1 Tonn=1.000 Kg*)
- Il petrolio serve anche per il trasporto delle materie prime alle fabbriche, dalle fabbriche ai punti vendita e dai negozi a casa.



IMPRONTA DI CARBONIO NASCOSTA

- 1,1 Kg di CO_2 per un vasca da bagno piena di acqua calda
- 500 g di CO_2 per una doccia di 6 minuti.
- In media, 3,5 Kg di CO_2 per la produzione di 1Kg di plastica per la produzione di flaconi di detergenti per il corpo

MANGIARE (FOGLIO 1)



ACQUA NASCOSTA

- Dietro alla <u>produzione di cibo</u> (vedi **immagine piramide FIG. 1 ALLEGATA**).

- Dietro alla produzione degli <u>imballaggi</u> dei prodotti alimentari che compriamo (**vedi grafico FIG. 2 ALLEGATA**). N.B: gli imballaggi rappresentano il 23% della spesa e diventano subito rifiuti!

Per il calcolo dell'impronta degli imballaggi considerare:

1. il peso medio di una scatola di alimenti (merendine, pasta, patatine, e…) è di 20g

2. il peso medio di un barattolo di alluminio (tonno, mais, pomdori, ecc..) è di 30 g

3. il peso medio di un barattolo di vetro o bottiglia è di 50 g.

RISORSE DEL SUOLO NASCOSTE:

- Dietro alla <u>produzione di cibo</u> :

a<u>. Un ettaro di terra (10.000 m2) può sfamare 1 persona al mese</u> considerando le colture di mais, grano, legumi, verdure e gli allevamenti (bovini, ovini, di polli, ecc). In peso corrispondono a circa 20.000 tonnellate di suolo. *1 tonn= 1.000 kg*

b. Per una sola barretta di cioccolato servono circa 2,5 m2 di suolo

- Per gli <u>imballaggi e le confezioni</u> dei prodotti alimentari:

  a. Per 1 tonnellata di alluminio servono 4 tonnellate di bauxite per ricavare i quali si devono scavare almeno il triplo di tonnellate di roccia.

b. Per produrre una tonnellata di plastica dei flaconi dei saponi ci vogliono almeno 1,5 tonnellate di petrolio.

c. per ricavare cellulosa da cui produrre 1oo kg di carta nuova servono 15 alberi e quindi una superficie di terreno in media di

IMPRONTA DI CARBONIO NASCOSTA:

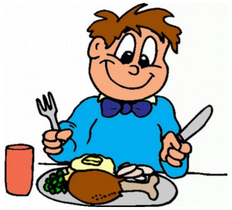
Dietro alla coltivazione, produzione, trasporto per la vendita di tutti i prodotti alimentari c'è emissione di CO2. Ecco alcuni esempi:

- ✓ 1 mela → 80 g CO2
- ✓ 1 banana → 80 g di CO2
- ✓ 1 tè o un caffè → 21 g di CO2
- ✓ 1 cappuccino → 235 g di CO2
- ✓ mezzo litro di latte → 723 g di CO2 (per allevamento, bottiglie di plastica, trasporti)

N.B.: il latte incide notevolmente sull'impronta di carbonio!

- ✓ 1 Kg di fragole → 600 g di CO2 (che aumenta a 1,8 Kg se coltivate fuori stagionee importate via aerea)
- ✓ 1 Kg di carote → 0,3 Kg di CO2
- ✓ 1 gelato alle creme → 500 g di CO2contro i soli 50 g per un ghiacciolo
- ✓ 1 Kg di patate → 620 g di CO2
- ✓ 1 Kg di pomodori → 9 Kg di CO2
- ✓ 1 Kg di pane → 1Kg di CO2

MANGIARE
(FOGLIO 2)



- Ma quanto ne viene sprecato!!!!

540 m2.

-Per il calcolo dell’impronta degli imballaggi considerare:
1. il peso medio di una scatola di alimenti (merendine, pasta, patatine, e…) è di 20g
2. il peso medio di un barattolo di alluminio (tonno, mais, pomdori, ecc..) è di 30 g
3. il peso medio di un barattolo di vetro o bottiglia è di 50 g.

- ✓ 1 cheeseburger → 2,5 Kg di CO_2 contro meno della metà (1Kg) per un hamburger vegetale
- ✓ 1 Kg di riso → 4 Kg di CO_2 (dovuto soprattutto al metano delle risaie e ai fertilizzanti impiegati)
- ✓ 1 bistecca → 2 Kg di CO_2
- ✓ 1 confezione di uova → 1,8 Kg di CO_2
- ✓ 1Kg di formaggio: 12 Kg di CO_2
- ✓ lavare i piatti → 550 g di CO_2 se lavati a mano usando acqua in modo molto parsimonioso e non troppo calda, ma può arrivare a 8 Kg se si usa abbondante acqua; 770 g di CO_2 in lavastoviglie a 55° C
- ✓ 1 tonnellata di fertilizzante usato in agricoltura: 2,7 tonnellate di CO_2 se utilizzato con parsimonia ma può aumentare fino a 12,3 se il fertilizzante è prodotto in maniera inefficiente ed usato in eccesso.

SCUOLA/STUDIO POMERIDIANO 	**ACQUA NASCOSTA:** ➢ per produrre un normale foglio di carta A4 vergine (nuova) servono 10 l di acqua, contro gli 0,2 l per un foglio di carta riciclata.	**RISORSE DEL SUOLO NASCOSTE** ➢ da un albero si possono ricavare fino a 200 risme di carta riciclata e per piantare un albero serve una superficie di innesto di 36 m2 di suolo.	**IMPRONTA DI CARBONIO NASCOSTA:** *Il problema della DEFORESTAZIONE (per pascoli, imprese agricole, agricoltura, intensiva, per ricavare legname, carta, per scavi minerari e costruzioni) ha una impronta del carbonio massiccia.* *Un ettaro (10.000 m2) di deforestazione produce 500 tonnellate di CO_2.*
VESTIRSI (FOGLIO 1) 	**ACQUA NASCOSTA** ➢ Per ottenere 1 kg di cotone tessile (tra acqua per piantagioni di cotone e produzione industriale) ci vogliono in media 11.000 litri di acqua. Quindi per una maglietta di 250 grammi occorrono 2.700 litri di acqua.  ➢ Per un paio di jeans 7600 l di acqua (impronta idrica elevata per il fatto di essere in cotone e per le operazioni di tintura)  ➢ Per i tessuti sintetici: a. viscosa: per 1 Kg di viscosa	**RISORSE DEL SUOLO NASCOSTE** Considerando un abbigliamento tipo di una giornata: ➢ Per un paio di scarpe in pelle o un giubbetto in pelle vengono impiegati 18 m2 di suolo (per l'allevamento animale e il foraggiamento) ➢ Per una t-shirt circa 4 m2 di suolo ➢ per un paio di jeans 6 m2 di suolo *Cotone: la maggior parte del cotone è coltivata in India, Uzbekistan, Argentina, Pakistan.*	**IMPRONTA DI CARBONIO NASCOSTA:** Se consideriamo le coltivazioni di fibre naturali e l'allevamento per i capi in pelle e lana, nonché la produzione industriale di fibre sintetiche (non naturali) anche per l'abbigliamento c'è un certa impronta del carbonio. ➢ Per un kg di cotone: 7 Kg di CO_2 ➢ Per un paio di pantaloni sintetici : 3 Kg di CO_2 ➢ per un paio di jeans di cotone 6 Kg di CO_2 (considerando le operazioni di tintura, taglio e cucitura) ➢ per un paio di scarpe:11,5 Kg in media contro i 15 Kg per quelle in pelle

VESTIRSI (FOGLIO 2)	di viscosa servono 3.000 l di acqua b. poliestere: per 1 Kg servono 71.000 l ➢ per un paio di scarpe di pelle o un giubbetto di pelle 8.000 l di acqua ➢ per un paio di scarpe da ginnastica: 5.000		
USO DELLE TECNOLOGIE 	**ACQUA NASCOSTA** ➢ Per uno smartphone servono 10 tonnellate di acqua	**RISORSE DEL SUOLO NASCOSTE:** ➢ Per la produzione di uno smartphone servono 18 m2 di suolo. ➢ l'estrazione dei suoi ingredienti (minerali componenti) dalla Terra richiede 30 Kg di roccia 	**IMPRONTA DI CARBONIO NASCOSTA:** ➢ 0,014 g di CO_2 per un messaggio ➢ una chiacchierata di 1 minuto al cellulare corrisponde a 57 g di emissioni ➢ 0,7 g di CO_2 per una singola ricerca sul web ➢ 4 g di CO_2 per una e-mail ➢ 50 g di CO_2 per una e-mail con un allegato ➢ per un computer: a. 200 Kg di CO_2 per la produzione b. 12 g di CO_2 all'ora per il consumo energetico c. 50 g di CO_2 all'ora per uso delle ret

ATTIVITA'
-ZAINO ECOLOGICO-

NOME GRUPPO:…………………………………………...CLASSE……………………...DATA…………………………...
SEGRETARIO:…………………………..ECOLOGISTA:…………………………….MATEMATICO:……………………………
CAPOGRUPPO:………………………………..

SUGGERIMENTI PER I CALCOLI MATEMATICI:

- ✓ 1 tonnellata= 1.000 Kg
- ✓ 1Kg di acqua= 1litro
- ✓ 1 l di petrolio= 1 Kg
- ✓ Se avete che per produrre 1 Kg di prodotto servono ad es. 2.500 l di acqua, allora per 1g di prodotto servono 2.500:1.000= 2,5 l di acqua

AZIONE DEL GRUPPO	CONSUMO RISORSA ACQUA (IMPRONTA IDRICA)	CONSUMO RISORSA SUOLO (IMPRONTA DI SUOLO)	IMPRONTA DI CARBONIO
1. Bere	Acqua visibile: quanti l di acqua bevuti dal gruppo in un giorno?.... …………………….. …………………………... Acqua "nascosta": pensate alle bottiglie di plastica delle bevande che il gruppo consuma in un giorno e calcolate l'impronta idrica. ….. ....……………………………... ………………………………………...	Consumo "nascosto" di suolo:pensate a quante bottiglie di plastica e quindi litri di petrolio consumati) butta il gruppo in un giorno ….. ....……... …………………………………………… …………………………………………… …………………………………………… …………………………………………… …………………………………………	Calcolate l'impronta di carbonio delle bottiglie di plastica usate dal gruppo in un giorno (una bottiglia da 1,5 l di acqua pesa circa 35 g, 16 una da mezzo litro): ………………………………………. ………………………………………. ………………………………………. ………………………………………. ………………………………………. ………………………………………. ………………………………………. ………………………………………. ….

2. Lavarsi	Acqua visibile: Pensate alle azioni di lavaggio fatte dal gruppo durante la giornata e calcolate i litri di acqua totali consumati per le seguenti azioni: - lavarsi mani e viso…………… - fare il bagno in vasca………… - fare la doccia…………………….. - tirare lo sciacquone del water…….. - lavarsi i denti…………………..	Consumo "nascosto" di suolo: pensate a quanti flaconi di plastica di saponi, shampoo, bagnoschiuma usati dal gruppo in un giorno (una bottiglia da 250 ml pesa circa 30 g). …... ....…………………………………….. ………………………………………… ………………………………………...	Calcolate l'impronta di carbonio delle bottiglie di plastica di saponi, shampoo, bagnoschiuma usati dal gruppo in un giorno (una bottiglia da 250 ml pesa circa 30 g). …………………………………… …………………………………… …………………………………… …………………………………… …………………………………….
	Acqua "nascosta": pensate alle bottiglie di plastica, flaconi di saponi e shampoo eventualmente buttati dal gruppo in un giorno. Pensate anche all'uso di dentifricio e sapone. ……………………………………… ……………………………………… ……………………………………… ……………………………………… ……………………………………… ……………………………………… ……………………………………..		
3. Mangiare (Cibo)	Acqua "nascosta": pensate ai **pasti** del gruppo della giornata e calcolate l'impronta idrica del gruppo. 1.Colazione:....................................... ....…	Consumo "nascosto" di suolo : calcolate, in maniera approssimativa, quanti Kg di suolo servono a **sfamare** i componenti del vostro gruppo in un mese. ………………………………………… …………………………………………	Calcolate l'impronta di carbonio dei **pasti** del gruppo della giornata. 1.Colazione: …………………………………… …………………………………… …………………………………… ……………………………………

	2. Merenda mattiniera …………………………. ....…………………... 3.Pranzo:...……………………..... 4. Merenda pomeridiana:... 5.Cena..…	…….	2. Merenda mattiniera: ……………………………………………………………………………………………… 3.Pranzo: ……………………………………………………………………………………………………….. 4. Merenda pomeridiana: …………………………………………………………………………… 5. Cena: ………………………………………………………………………..
Mangiare (Confezioni degli alimenti)	Acqua "nascosta": pensate agli **imballaggi** di cibo buttati e calcolate l' impronta idrica totale (per i pesi degli imballaggi guardate scheda di riferimento): ....………..	Consumo "nascosto" di suolo: pensate agli **imballaggi** di cibo buttati e calcolate l' impronta di suolo totale per i pesi degli imballaggi guardate scheda di riferimento): …….	Calcolate l'impronta di carbonio degli **imballaggi** buttati via in una giornata. Tenete conto che: 1. In media, 3,5 Kg di CO2 per la produzione di 1Kg di plastica ……………………………………………………………………... 2.In media, 3Kg di CO2 per ogni chilo di carta. ……………………………………………………………………………………………………… 3. In media, 8 Kg di CO2per ogni chilo di alluminio. ……

5. Vestirsi	Acqua “nascosta”: Osservate il vestiario di ogni componente del gruppo di oggi (maglietta, felpa, scarpe, pantaloni.....) e calcolate l'impronta idrica del gruppo (controllando l'etichetta per il materiale di cui è fatto): …..	Consumo “nascosto” di suolo: osservate il vestiario di ogni componente del gruppo di oggi (maglietta, felpa, scarpe, pantaloni.....) e calcolate l'impronta idrica del gruppo (controllando l'etichetta per il materiale di cui è fatto): …...	Calcolate l’impronta di carbonio del vestiario di oggi del gruppo. ………..
6. Uso delle nuove tecnologie	Acqua “nascosta”: considerata l’impronta idrica di tutti i cellulari del gruppo. …...	Consumo “nascosto” di suolo : considerate tutti i cellulari del gruppo e calcolate il consumo di suolo totale …...	Calcolate l’impronta di carbonio dell’uso in una giornata dei cellulari del gruppo: messaggi, chiamate, ricerche on-line, ecc…. …………………………………………………………………………..

LO ZAINO ECOLOGICO DEL GRUPPO (NOME)……………………………..E’ COSI’ COMPOSTO:

- **PESO ACQUA:**
- **PESO SUOLO E RISORSE MINERARIE (CHILI DI PETROLIO E MINERALE BAUXITE):**
- **PESO CO2 EMESSA:**

PESO TOTALE ZAINO:……………………………………………………………………………..
IL NOSTRO ZAINO PESA:………………VOLTE IL PESO DELLO ZAINO ECOLOGICO CAMPIONE (100 L DI ACQUA+ 100kG DI SUOLO+ 100 G DI CO2

QUESTIONARIO DI VALUTAZIONE SUL CONSUMO CONSAPEVOLE DI RISORSE ATTIVITA' (per studenti)

Questionario pre-attività

*Campo obbligatorio

1. 1. Hai mai sentito parlare dell'agenda 2030? *

Contrassegna solo un ovale.

- SI
- No

2. 2. Scegli nell'elenco qui sotto quello che consideri una risorsa (più di una risposta possibile): *

Seleziona tutte le voci applicabili.

- [ ] Acqua
- [ ] Suolo
- [ ] Minerali
- [ ] Rifiuti
- [ ] Scarti alimentari
- [ ] Gas di scarico delle auto
- [ ] Un paio di jeans
- [ ] Il mio cellulare rotto
- [ ] Un vecchio frullatore

3. 3. Segna le risorse che secondo te vengono utilizzate nella produzione dei seguenti oggetti: *

Seleziona tutte le voci applicabili.

	ACQUA	SUOLO	ENERGIA	RISORSE MINERARIE
1 maglietta di cotone	☐	☐	☐	☐
1 Kg di carne	☐	☐	☐	☐
1 Kg di plastica	☐	☐	☐	☐
1Kg di verdura	☐	☐	☐	☐
1 cellulare	☐	☐	☐	☐
1 televisione	☐	☐	☐	☐

4. 4. Metti una x nella casella scelta:

Contrassegna solo un ovale per riga.

	1=per niente d'accordo	2=poco d'accordo	3= d'accordo	4= molto d'accordo	5= del tutto d'accordo
E' importante comprare oggetti sempre nuovi	⬭	⬭	⬭	⬭	⬭
E' importante utilizzare oggetti usati	⬭	⬭	⬭	⬭	⬭
Le risorse naturali non finiscono	⬭	⬭	⬭	⬭	⬭
E' meglio utilizzare cibi confezionati	⬭	⬭	⬭	⬭	⬭
E' meglio utilizzare cibi confezionati solo con imballaggi riciclati	⬭	⬭	⬭	⬭	⬭
I rifiuti sono una risorsa	⬭	⬭	⬭	⬭	⬭
E' importante acquistare cellulari di ultima generazione	⬭	⬭	⬭	⬭	⬭

5. 5. Metti in ordine di importanza le seguenti azioni: *

Contrassegna solo un ovale per riga.

	1	2	3	4	5
RICICLARE	⬭	⬭	⬭	⬭	⬭
RIUSARE	⬭	⬭	⬭	⬭	⬭
RIPARARE	⬭	⬭	⬭	⬭	⬭
RISPETTARE	⬭	⬭	⬭	⬭	⬭
RIDURRE	⬭	⬭	⬭	⬭	⬭

Passa alla domanda 6.

QUESTIONARIO DI VALUTAZIONE SUL CONSUMO CONSAPEVOLE DI RISORSE PRE-ATTIVITA' CLASSE 1E

Questionario pre-attività

6. 1. Hai mai sentito parlare dell'agenda 2030? *

Contrassegna solo un ovale.

- SI
- No

7. 2. Scegli nell'elenco qui sotto quello che consideri una risorsa (più di una risposta possibile): *

Seleziona tutte le voci applicabili.

- [ ] Acqua
- [ ] Suolo
- [ ] Minerali
- [ ] Rifiuti
- [ ] Scarti alimentari
- [ ] Gas di scarico delle auto
- [ ] Un paio di jeans
- [ ] Il mio cellulare rotto
- [ ] Un vecchio frullatore

8. 3. Segna le risorse che secondo te vengono utilizzate nella produzione dei seguenti oggetti: *

Seleziona tutte le voci applicabili.

	ACQUA	SUOLO	ENERGIA	RISORSE MINERARIE
1 maglietta di cotone	☐	☐	☐	☐
1 Kg di carne	☐	☐	☐	☐
1 Kg di plastica	☐	☐	☐	☐
1Kg di verdura	☐	☐	☐	☐
1 cellulare	☐	☐	☐	☐
1 televisione	☐	☐	☐	☐

9. 4. Metti una x nella casella scelta:

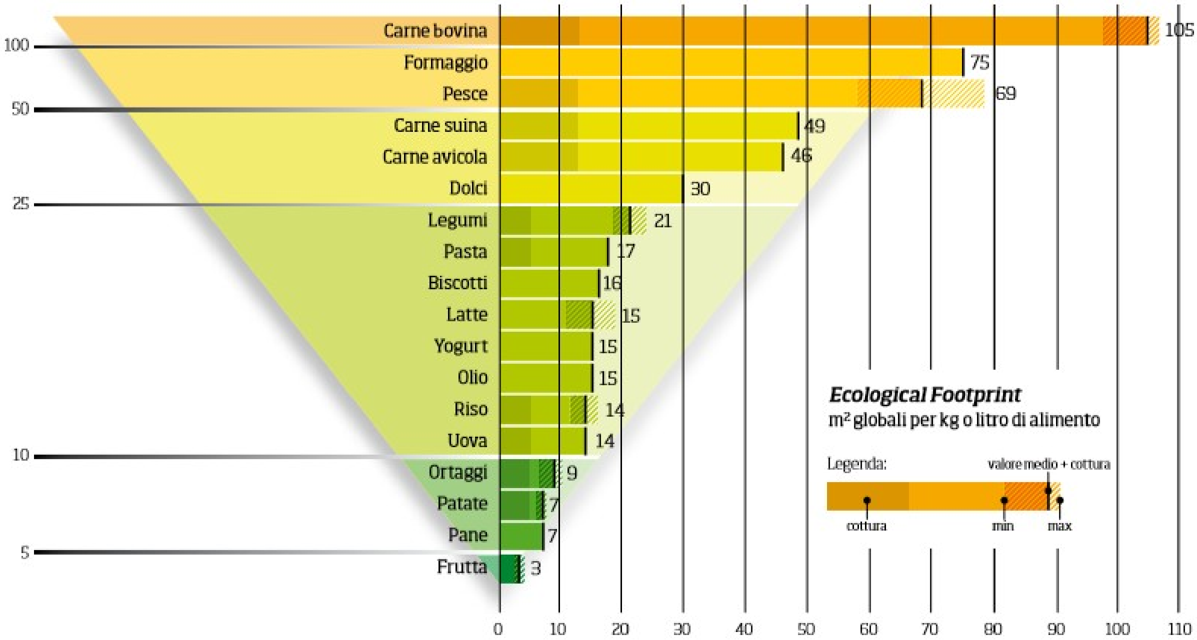
Contrassegna solo un ovale per riga.

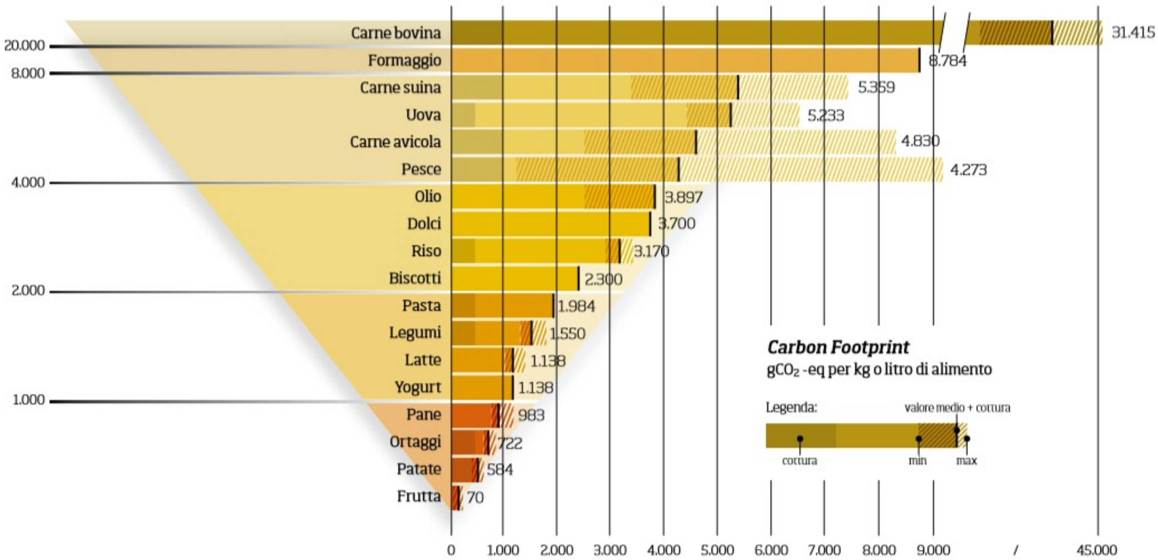
	1=per niente d'accordo	2=poco d'accordo	3= d'accordo	4= molto d'accordo	5= del tutto d'accordo
E' importante comprare oggetti sempre nuovi	⬭	⬭	⬭	⬭	⬭
E' importante utilizzare oggetti usati	⬭	⬭	⬭	⬭	⬭
Le risorse naturali non finiscono	⬭	⬭	⬭	⬭	⬭
E' meglio utilizzare cibi confezionati	⬭	⬭	⬭	⬭	⬭
E' meglio utilizzare cibi confezionati solo con imballaggi riciclati	⬭	⬭	⬭	⬭	⬭
I rifiuti sono una risorsa	⬭	⬭	⬭	⬭	⬭
E' importante acquistare cellulari di ultima generazione	⬭	⬭	⬭	⬭	⬭

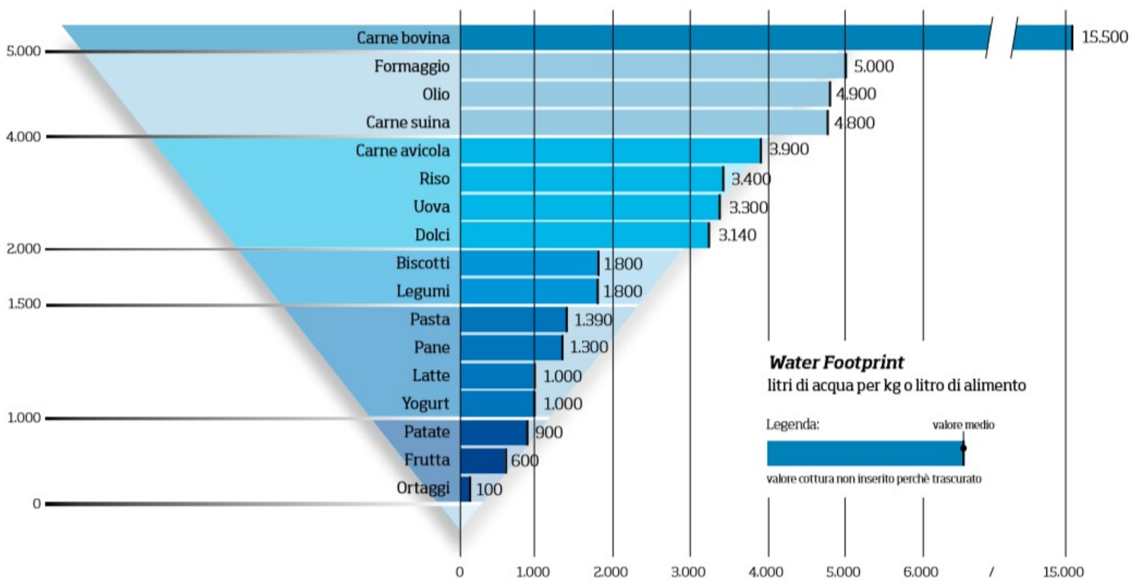
10. 5. Metti in ordine di importanza le seguenti azioni: *

Contrassegna solo un ovale per riga.

	1	2	3	4	5
RICICLARE	⬭	⬭	⬭	⬭	⬭
RIUSARE	⬭	⬭	⬭	⬭	⬭
RIPARARE	⬭	⬭	⬭	⬭	⬭
RISPETTARE	⬭	⬭	⬭	⬭	⬭
RIDURRE	⬭	⬭	⬭	⬭	⬭


Carne bovina 105
Formaggio 75
Pesce 69
Carne suina 49
Carne avicola 46
Dolci 30
Legumi 21
Pasta 17
Biscotti 16
Latte 15
Yogurt 15
Olio 15
Riso 14
Uova 14
Ortaggi 9
Patate 7
Pane 7
Frutta 3
100
50
25
10
5
0 10 20 30 40 50 60 70 80 90 100 110
Ecological Footprint
m² globali per kg o litro di alimento
Legenda:
valore medio + cottura
cottura
min
max


Carne bovina 31.415
Formaggio 8.784
Carne suina 5.359
Uova 5.233
Carne avicola 4.830
Pesce 4.273
Olio 3.897
Dolci 3.700
Riso 3.170
Biscotti 2.300
Pasta 1.984
Legumi 1.550
Latte 1.138
Yogurt 1.138
Pane 983
Ortaggi 722
Patate 584
Frutta 70
20.000
8.000
4.000
2.000
1.000
0 1.000 2.000 3.000 4.000 5.000 6.000 7.000 8.000 9.000 / 45.000
Carbon Footprint
gCO₂-eq per kg o litro di alimento
Legenda:
valore medio + cottura
cottura
min
max


Carne bovina 15.500
Formaggio 5.000
Olio 4.900
Carne suina 4.800
Carne avicola 3.900
Riso 3.400
Uova 3.300
Dolci 3.140
Biscotti 1.800
Legumi 1.800
Pasta 1.390
Pane 1.300
Latte 1.000
Yogurt 1.000
Patate 900
Frutta 600
Ortaggi 100
5.000
4.000
2.000
1.500
1.000
0
0 1.000 2.000 3.000 4.000 5.000 6.000 / 15.000
Water Footprint
litri di acqua per kg o litro di alimento
Legenda:
valore medio
valore cottura non inserito perchè trascurato

QUANTO E' SOSTENIBILE LA MIA ALIMENTAZIONE?

Con questa attività, calcoliamo il punteggio di ogni squadra,

ma qui "vince" chi raggiunge il

MINOR PUNTEGGIO: MINORE IMPATTO AMBIENTALE

Calcola i punti totalizzati osservando il tuo "*piatto alimentare*" mettendo, per ogni prodotto scelto, il punteggio su ogni tabella:

1. Tenendo conto del tipo di alimento o bevanda:

FRUTTA E ORTAGGI DI STAGIONE E PAPATE  **PUNTI:1**	**N.PEZZI:** ……………… **PUNTEGGIO:** ……………….	**LEGUMI E FRUTTA SECCA**  **PUNTI: 4**	**N.PEZZI:** ……………… **PUNTEGGIO:** ……………….
FRUTTA E VERDURA NON DI STAGIONE  **PUNTI: 3**	**N.PEZZI:** ……………… **PUNTEGGIO:** ………………	**OLIO, CARNE DI POLLO, CARNE DI MAIALE**  **PUNTI: 5**	**N.PEZZI:** ……………… **PUNTEGGIO:** ……………….
LATTE, PANE, RISO  **PUNTI: 2**	**N.PEZZI:** ……………… **PUNTEGGIO:** ………………	**PESCE E FORMAGGIO**  **PUNTI: 6**	**N.PEZZI:** ……………… **PUNTEGGIO:** ……………….
BISCOTTI, PASTA, DOLCI, YOGURT  **PUNTI: 3**	**N.PEZZI:** ……………… **PUNTEGGIO:** ………………	**CARNE BOVINA**  **PUNTI: 7**	**N.PEZZI:** ……………… **PUNTEGGIO:** ……………….

TOT PUNTI IMPATTO AMBIENTALE PER TIPO DI ALIMENTO:………

2. Tenendo conto del tipo di imballaggio:

SOLO CARTA 100% ma fino a 7 ricicli **PUNTI:2**	**N.PEZZI:** ……………… **PUNTEGGIO:** ……………….	**POLIACCOPPIATO** (si ricicla ma con maggiore lavorazione e non sempre al 100%) **PUNTI:4**	**N.PEZZI:** ……………… **PUNTEGGIO:** ……………….
SOLO PLASTICA (non riciclabile al 100% e dipende dalla qualità della plastica) **PUNTI: 3**	**N.PEZZI:** ……………… **PUNTEGGIO:** ……………….	**ALLUMINIO** Riciclabile al 100% per infinte volte **PUNTI: 2**	**N.PEZZI:** ……………… **PUNTEGGIO:** ……………….
PIU' IMBALLAGGI (uno interno ed uno esterno di diverso materiale) **PUNTI: 5**	**N.PEZZI:** ……………… **PUNTEGGIO:** ……………….	**VETRO** Riciclabile al 100% per infinte volte **PUNTI: 2**	**N.PEZZI:** ……………… **PUNTEGGIO:** ……………….
PRODOTTO NON CONFEZIONATO **PUNTI:1**	**N.PEZZI:** ……………… **PUNTEGGIO:** ……………….		**N.PEZZI:** ……………… **PUNTEGGIO:** ……………….
TOT PUNTI IMPATTO AMBIENTALE PER TIPO DI IMBALLAGGIO:…………			

3. Tenendo conto del luogo di produzione (più lunga è la filiera produttiva, più lungo è il trasporto e quindi l'impronta di carbonio)

NON UE **Punti: 6**	**N.PEZZI:** **………………** **PUNTEGGIO:** **……………….**
UE/NON UE **PUNTI:5**	**N.PEZZI:** **………………** **PUNTEGGIO:** **……………….**
UE **PUNTI: 4**	**N.PEZZI:** **………………** **PUNTEGGIO:** **……………….**
ITALIA **PUNTI: 2**	**N.PEZZI:** **………………** **PUNTEGGIO:** **……………….**
KM0 (Marche) **PUNTI:1**	**N.PEZZI:** **………………** **PUNTEGGIO:** **……………….**
TOT PUNTI IMBATTO AMBIENTALE A SECONDA DELLA PROVENIENZA:….	

4. Particolari certificazioni che riducono l'impronta ecologica:

Nessuna certificazione **PUNTI:5**	**N.PEZZI:** ……………… **PUNTEGGIO:** ……………….
Certificazione di agricoltura biologica **PUNTI: 1**	**N.PEZZI:** ……………… **PUNTEGGIO:** ……………….
Certificazione agricoltura integrata **PUNTI: 1**	**N.PEZZI:** ……………… **PUNTEGGIO:** ……………….
Certificazione di pesca sostenibile **PUNTI: 1**	**N.PEZZI:** ……………… **PUNTEGGIO:** ……………….
Certificazione di allevamento biologico **PUNTI: 1**	**N.PEZZI:** ……………… **PUNTEGGIO:** ……………….
Certificazione RAINFOREST **PUNTI: 1**	**N.PEZZI:** ……………… **PUNTEGGIO:** ……………….

TOT PUNTI IMBATTO AMBIENTALE PER PRESENZA DI EVENTUALI CERTIFICAZIONI:

TOTALE PUNTI SQUADRA: …………………………..

VINCE CHI HA SCELTO I PRODOTTI A MINORE IMPATTO AMBIENTALE!

IL PIATTO ALIMENTARE-AMBIENTALE

Con questa attività, valutiamo e calcoliamo il punteggio del "piatto alimentare-ambientale del giorno" di ogni gruppo. E' una sorta di "gioco a punti" ,ma qui "vince" chi raggiunge il MINOR PUNTEGGIO: MINORE IMPATTO AMBIENTALE.

	FRUTTA (anche secca e succhi di frutta, marmellate)						
	Descrizione	**Impronte idrica, del carbonio, ecologica** (vedi scheda allegata piramidi alimentari**)**	**Origine del prodotto** (da chi è prodotto, dove)	**Punti impatto per tipo di alimento** (vedi scheda punteggi allegata, pag. 1)	**Punti impatto per tipo di imballaggio** (vedi scheda allegata punteggi pag. 2)	**Punti impatto a seconda del luogo di provenienza**	**Punti per particolari certificazioni che riducono l'impronta**
Pezzo 1		Idrica: Del carbonio: Ecologica:					
Pezzo2		Idrica: Del carbonio: Ecologica:					
Pezzo3		Idrica: Del carbonio: Ecologica:					
Pezzo 4		Idrica: Del carbonio: Ecologica:					

	ORTAGGI E LEGUMI						
	Descrizione	**Impronte idrica, del carbonio, ecologica** (vedi scheda allegata piramidi alimentari**)**	**Origine del prodotto** (da chi è prodotto, dove)	**Punti impatto per tipo di alimento** (vedi scheda punteggi allegata, pag. 1)	**Punti impatto per tipo di imballaggio** (vedi scheda allegata punteggi pag. 2)	**Punti impatto a seconda del luogo di provenienza**	**Punti per particolari certificazioni che riducono l'impronta**
Pezzo 1		Idrica: Del carbonio: Ecologica:					
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Pezzo3		Idrica: Del carbonio: Ecologica:					
Pezzo 4		Idrica: Del carbonio: Ecologica:					

PUNTI IMPATTO TOTALI:………………………………………………………….

	LATTE, YOGURT, FORMAGGI						
	Descrizione	**Impronte idrica, del carbonio, ecologica** (vedi scheda allegata piramidi alimentari**)**	**Origine del prodotto** (da chi è prodotto, dove)	**Punti impatto per tipo di alimento** (vedi scheda punteggi allegata, pag. 1)	**Punti impatto per tipo di imballaggio** (vedi scheda allegata punteggi pag. 2)	**Punti impatto a seconda del luogo di provenienza**	**Punti per particolari certificazioni che riducono l'impronta**
Pezzo 1		Idrica: Del carbonio: Ecologica:					
Pezzo2		Idrica: Del carbonio: Ecologica:					
Pezzo3		Idrica: Del carbonio: Ecologica:					
Pezzo 4		Idrica: Del carbonio: Ecologica:					

PUNTI IMPATTO TOTALI:...

	PASTA, PANE, RISO						
	Descrizione	**Impronte idrica, del carbonio, ecologica** (vedi scheda allegata piramidi alimentari**)**	**Origine del prodotto** (da chi è prodotto, dove)	**Punti impatto per tipo di alimento** (vedi scheda punteggi allegata, pag. 1)	**Punti impatto per tipo di imballaggio** (vedi scheda allegata punteggi pag. 2)	**Punti impatto a seconda del luogo di provenienza**	**Punti per particolari certificazioni che riducono l'impronta**
Pezzo 1		Idrica: Del carbonio: Ecologica:					
Pezzo2		Idrica: Del carbonio: Ecologica:					
Pezzo3		Idrica: Del carbonio: Ecologica:					
Pezzo 4		Idrica: Del carbonio: Ecologica:					

PUNTI IMPATTO TOTALI:………………………………………………………

	DOLCI (anche cioccolato) E BISCOTTI						
	Descrizione	**Impronte idrica, del carbonio, ecologica** (vedi scheda allegata piramidi alimentari**)**	**Origine del prodotto** (da chi è prodotto, dove)	**Punti impatto per tipo di alimento** (vedi scheda punteggi allegata, pag. 1)	**Punti impatto per tipo di imballaggio** (vedi scheda allegata punteggi pag. 2)	**Punti impatto a seconda del luogo di provenienza**	**Punti per particolari certificazioni che riducono l'impronta**
Pezzo 1		Idrica: Del carbonio: Ecologica:					
Pezzo2		Idrica: Del carbonio: Ecologica:					
Pezzo3		Idrica: Del carbonio: Ecologica:					
Pezzo 4		Idrica: Del carbonio: Ecologica:					

PUNTI IMPATTO TOTALI:……………………………………………………………

	CARNE E PESCE						
	Descrizione	**Impronte idrica, del carbonio, ecologica** (vedi scheda allegata piramidi alimentari**)**	**Origine del prodotto** Per carne: dove è nata ed allevata Per pesce: tipo di pesca e zona di pesca	**Punti impatto per tipo di alimento** (vedi scheda punteggi allegata, pag. 1)	**Punti impatto per tipo di imballaggio** (vedi scheda allegata punteggi pag. 2)	**Punti impatto a seconda del luogo di provenienza**	**Punti per particolari certificazioni che riducono l'impronta**
Pezzo 1		Idrica: Del carbonio: Ecologica:					
Pezzo2		Idrica: Del carbonio: Ecologica:					
Pezzo3		Idrica: Del carbonio: Ecologica:					
Pezzo 4		Idrica: Del carbonio: Ecologica:					

PUNTI IMPATTO TOTALI:………………………………………………………


S-City
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DOMANDONE
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TEAMWORK
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TEAMWORK
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TEAMWORK
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46

Consideravano l'oro talmente prezioso da attribuirgli un valore divino e hanno mantenuto per mille anni, per estrarlo, colonie minerarie in quello che oggi è il Sudan meridionale:

a) Babilonesi
b) Greci
c) Egizi
d) Romani

Risposta: C

L'oro è una risorsa mineraria che l'uomo da sempre ha cercato e desiderato, ancor prima di lavorare il ferro e il bronzo. Il Sud Africa, pur ricco di miniere, rimane ancora oggi uno dei Paesi più poveri al mondo

Alle soglie della caduta dell'Impero Romano nasce la "servitù della gleba", ex schiavi o ex piccoli proprietari legati al proprio terreno a vita. Infatti la parola "gleba" significa:

a) Suolo
b) Zolla
c) Terreno
d) Agricoltura

Risposta: B

Il terreno e il suolo, in quanto preziosa risorsa da sempre nella storia ha rivestito un valore anche di propria identità. I servi della gleba rimanevano legati al proprio terreno a vita.

L'imperatore Carlo Magno fece coniare una nuova moneta (lira) che era fatta di:

a) Bronzo
b) Rame
c) Oro
d) Argento

Risposta: D

Le risorse minerarie del suolo sono così importanti da essere state utilizzate anche come valore di moneta.

Grazie soprattutto alla loro opere di irrigazione, coltivarono in modo abilissimo, nell'VIII sec. d.C., anche piante non alimentari come lino, gelso (per l'allevamento del baco da seta), cotone, favorendo il sorgere di importanti manifatture tessili.

a) Longobardi
b) Romani
c) Cinesi
d) Arabi

Risposta: C

Nascono le prime industrie tessili che utilizzano fibre naturali come il cotone e la seta che diventano merce di scambio con l'Occidente (via della Seta)

All'inizio del X secolo, i Vichinghi, grandi navigatori e pirati, provenienti dalla Scandinavia, abbandonarono la loro terra, non solo per depredare, ma anche per trovare un posto dove stabilirsi. Infatti, l'Europa del Nord era povera e fredda: la pesca e la scarsa agricoltura permettevano a malapena di sopravvivere.
Vero o Falso?

Risposta: VERO

Le condizioni ambientali, la temperatura e la disponibilità di risorse hanno da sempre condizionato il popolamento di un territorio.

Verso la fine del primo millennio, il paesaggio in Europa era molto diverso da quello attuale: aree coltivate abbondanti ed estese, a seguito di numerose opere di deforestazione. Vero o Falso?

Risposta: FALSO

Aree coltivate ridotte rispetto all'epoca romana, agricoltura e pesca scarsi (alimentazione quotidiana assai povera), paesaggio ricoperto da boschi e foreste.

STORIA

Vivere in un feudo significava vivere in una comunità con un'economia autosufficiente, cioè produceva al suo interno tutto il necessario. Potremmo vederlo come un antico "esperimento" di città sostenibile. Vero o falso?

Risposta: VERO

Questa economia autosufficiente veniva chiamata economia curtense : infatti la "curtis" o "corte" era l'insieme dei terreni e delle costruzioni su cui dominava il signore feudale

Nell'anno Mille la ripresa economica europea è dovuta ai seguenti fattori tranne uno:

a) coltivazione di campi interi a maggese
b) rotazione delle colture triennale
c) navigazione a vela
d) utilizzo di nuove fonti di energia (mulino a vento ruota ad acqua per macinare il grano)

Risposta: A

Questa tecnica consente di avere un terreno più fertile: questo perché tutte le piante o gli ortaggi necessitano di alcune sostanze piuttosto che altre e viceversa ne rilasciano nel terreno.

In Italia l'impronta idrica giornaliera di ogni cittadini equivale a circa:

a) 3400 l
b) 5000 l
c) 1400 l
d) Più di 6000 l

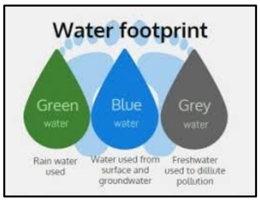
Risposta: D
L'impronta idrica relativa al consumo di cibo contribuisce all '89% dell'impronta idrica totale giornaliera degli italiani. IL consumo di acqua per usi domestici (pulire, cucinare, bere, ecc…) rappresenta solo il 4%, mentre l'acqua utilizzata nelle filiere produttive rappresenta il 7% del totale.

In media, ogni anno un italiano butta nella pattumiera una quantità di scarti alimentari e di giardinaggio pari a:

a) 80 Kg
b) 100 Kg
c) 150 Kg
d) 180 Kg

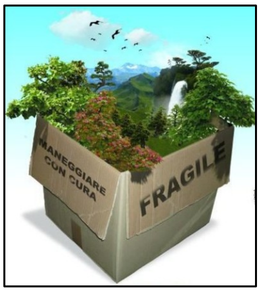
Risposta: C
In Italia ogni anno si buttano via 10 milioni di tonnellate di scarti che un tempo avrebbero alimentato animali o terreni.

Il *water footprint* (impronta idrica) si suddivide in tre componenti: blu, verde e grigia. Quella verde riguarda le acque superficiali e sotterranee usate per scopi agricoli e domestici.
VERO O FALSO?



Risposta: FALSO
Blu: acque superficiali e sotterranee usate per scopi agricoli e domestici.
Verde: volume di acqua piovana usata.
Grigia: volume di acqua necessaria per diluire gli inquinanti.

Per ogni Kg di rifiuti urbani che produciamo, consumiamo 100 Kg di risorse naturali. VERO O FALSO?



Risposta: VERO
Pensiamo a tutte le risorse impiegate per i processi produttivi e gli imballaggi!

Secondo la Direttiva Comunitaria Europea, si definisce "rifiuto" una qualsiasi sostanza o un oggetto di cui il detentore si disfa o abbia intenzione o l'obbligo di disfarsi subito dopo l'acquisto. VERO O FALSO?

Risposta: VERO

Il riutilizzo di un rifiuto si differenzia dal riciclo poiché:
a) Serve solo la pulizia ed eventuale riparazione del prodotto.
b) È applicabile a tutti i rifiuti, tranne gli imballaggi
c) Non può essere fatto per il vetro.
d) È poco utile perché non permette di produrre oggetti diversi.

Risposta: A

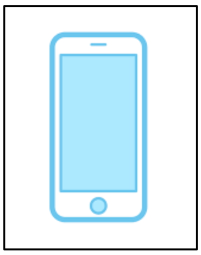
SCIENZE

Per paio di stivali in pelle servono 15 m² di suolo. VERO O FALSO?

Risposta: FALSO
Servono 50 m²!

Per uno Smarthpone servono:

a) 10 tonnellate di acqua
b) 100 Kg di acqua
c) 1 tonnellata di acqua
d) 20 tonnellate di acqua



Risposta: A

SCIENZE

SCIENZE

SCIENZE

SCIENZE

SCIENZE

SCIENZE

SCIENZE

SCIENZE

SCIENZE

Se per ricavare 5g di oro serve l'estrazione di una tonnellata di roccia, quanti kg di roccia servono per fare un anello da 25 grammi?

a) 1000 Kg
b) 250Kg
c) 5000 Kg
d) 25 tonnellate

Risposta:C
1.000x5= 5.000 Kg. Le fede nuziali si portano dietro un pesantissimo zaino ecologico!

Se per estrarre i materiali componenti di un cellulare si scavano 30Kg di roccia, quanti Kg di roccia sono stati consumati per la produzione italiana in un anno di 35.000.000 di smartphone?

a) 1.000.000.000 Kg
b) 95.000.000 Kg
c) 30.000.000 kg
d) 1.050.000 Kg

Risposta:D
30x35.000.000=1.050.000.000 Kg!

Se dal riciclo di 50.000 cellulari si ottiene 1Kg di oro, si potrebbero fabbricare 50 anelli d'oro da 10 g. VERO O FALSO?

Risposta:FALSO
1.000:10=100 anelli d'oro!

L'impronta idrica di una dieta a base di carne è di 3.600l di acqua al giorno mentre di una dieta vegetariana è pari alla prima diminuita di 2.350l al giorno. La differenza quindi è di:

a) 1.250 l
b) 1.270 l
c) 1.000 l
d) 1.250 dl

Risposta: A
3.600 - 2.350 = 1.250 l.
E' già a tavole, con una dieta più equilibrata e un ridotto consumo di carne che possiamo già agire concretamente per uno sviluppo sostenibile.

Ogni giorno in Italia buttiamo via quasi 3.000.000.000 Kg di cibo ancora buono. Questo significa che, se in Italia siamo più di 60.000.000 di abitanti, ognuno di noi può arrivare ad uno spreco giornaliero di 5Kg.
VERO O FALSO?

Risposta: FALSO
3.000.000.000 : 60.000.000 = 50kg!

Una donna che lavora in Bangladesh producendo jeans per note catene di abbigliamento a basso costo guadagna 5.400 euro circa all'anno. La sua paga mensile è quindi circa di:

a) 1.250 l
b) 1.270 l
c) 1.000 l
d) 1.250 dl

Risposta: A
3.600 - 2.350 = 1.250 l.
E' già a tavole, con una dieta più equilibrata e un ridotto consumo di carne che possiamo già agire concretamente per uno sviluppo sostenibile.

MATEMATICA

L'impronta di carbonio di mezzo litro di acqua del rubinetto è di 0,14g di CO_2, contro i 160g di mezzo di litro di acqua in bottiglia di plastica. Smettere di bere acqua in bottiglia di plastica consente, pertanto, una riduzione delle emissioni di oltre 100 volte CO_2.
VERO O FALSO?

Risposta: FALSO
E' oltre 1.000 volte superiore!

Una ricerca sul web di 30sec (considerando l'energia utilizzata dai motori di ricerca e dal computer) ha un impronta del carbonio di circa 1g.
Se in media utilizziamo il web per un'ora al giorno, siamo responsabili dell'emissione di circa 120g di CO_2.
VERO O FALSO?

Risposta: VERO
In 60sec (1min) si emettono 2g di CO_2. 2 x 60 = 120g di CO_2 emessa.

E' un metallo duttile, malleabile ed indistruttibile, per questo impiegato dai dentisti per piccoli interventi di otturazione ai denti.

a) Ferro
b) Alluminio
c) Rame
d) Oro

Risposta: D
L'oro, risorsa molto importante del suolo è impiegato anche nella produzione di apparecchi elettronici.

Quale tra i seguenti non sono materie prime per la fabbricazione del vetro:

a) Bauxite
b) Sabbia
c) Calcare
d) Dolomite

Risposta: A
La bauxite è una delle materie prime utilizzate per la produzione dell'alluminio.

La produzione di 1kg di carta riciclata, rispetto ad 1 Kg di carta vergine, richiede una quantità di acqua:

a) Fino a 50 volte inferiore
b) La metà
c) Fino a 5 volte inferiore
d) Fino a 100 volte inferiore

Risposta: A
Infatti, per 1Kg di carta nuova servono fino a 100 litri di acqua, contro i 2 litri di acqua per la produzione di carta vergine.

Un' economia circolare si differenzia da una lineare perchè la vita dei prodotti non finisce con il loro consumo. VERO FALSO?

Risposta: VERO
In un'economia circolare, l'obiettivo principale è il riutilizzo per ridurre al minimo la produzione di rifiuti.

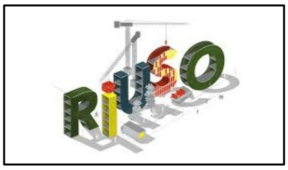
Quale fonte di energia ha minore impronta del carbonio?

a) Legno
b) Carbone
c) Energia solare
d) Gasolio

Risposta: C
L'applicazione ideale di energia solare si riscontra nella realizzazione di impianti medio-piccoli ad esempio per coprire il fabbisogno energetico di un'abitazione o di un'azienda.

Quando un oggetto, non ancora diventato rifiuto, viene utilizzato più volte con le stesse finalità, parliamo di:

a) Riuso
b) Riciclo
c) Riparazione
d) Riduzione del consumo



Risposta: A
Se il riuso è un'azione immediata e significa riutilizzare un oggetto che non è ancora diventato rifiuto, per la stessa finalità per cui erano già stati utilizzati in precedenza, riciclo invece, porta ad una vera e propria trasformazione.

TECNOLOGIA

Imprese che lavorano nell'ottica di un'economia circolare realizzano prodotti con l'idea di:

a) Durata
b) Riutilizzo
c) Riparazione
d) Tutte le precedenti

Risposta: D
In un'economia circolare, l'obiettivo principale è il riutilizzo per ridurre al minimo la produzione di rifiuti.

Alluminio e vetro sono:

a) Riciclabili al 100%
b) Riciclabili al 80%
c) Solo riutilizzabili
d) Nessuna delle precedenti

Risposta: A
Alluminio e vetro sono riciclabili completamente. Il loro recupero e riciclo, oltre ad evitare l'utilizzo di nuove risorse come la bauxite (alluminio) consente di risparmiare il 95% dell'energia richiesta per produrli dalle materie prime.

Un operaio di una miniera d'oro, in Sud Africa, per 11 ore di lavoro al giorno guadagna al mese (1 sterlina= 1,10 euro):

a) 140 sterline
b) 100 sterline
c) 300 sterline
d) 500 sterline

Risposta: A
Contro le 50.000 sterline dell'amministratore della compagnia che gestisce la miniera.

Un ricercatore che si è occupato di gestione dei rifiuti, ha paragonato la nostra pattumiera a:

a) Un macigno
b) Il luogo dove regna il caos
c) L'impronta digitale di ognuno
d) Un meteorite di impatto distruttivo sulla Terra

Risposta: C
La nostra pattumiera viene paragonata al nostro codice genetico, in quanto identificano e descrivono i nostri comportamenti (a volte errati o inconsapevoli)

Completa la frase con l'affermazione che ti sembra più adatta. Lo sviluppo sostenibile preserva gli ambienti naturali in quanto:

a)Deriva da una stretta collaborazione tra le imprese
b) Consente di utilizzare meno suolo
c) Limita il consumo di risorse naturali che da questi provengono e produce rifiuti e scarti che possono essere da questi ambienti assorbiti
d) Riduce l'impronta del carbonio

Risposta: C

Quali tra le seguenti potrebbero essere le caratteristiche di una città sostenibile (più di una risposta corretta):

a)Presenza di spazi che animano e coinvolgono la città e la comunità.
b) Mobilità sostenibile privilegiando percorsi pedonabili e ciclabili che consentano di muoversi agevolmente in città.
c) Sviluppo di zone verdi anche per mitigare la temperatura delle zone vicine.
d) Utilizzo di fonti di energia rinnovabili come quella solare ed eolica

Risposta: TUTTE

L'azione più efficace per ridurre il problema dello smaltimento dei rifiuti è quella di:

a) Lavare bene gli imballaggi e gettarli nell'apposito cestino della raccolta differenziata
b) Occhio all'etichetta
c) Comprare prodotti con imballaggi di vetro anzichè di plastica
d) Occhio alla spesa (compro solo quello che mi serve, cerco di ridurre il consumo)

Risposta: D
L'azione più decisiva è quella di comprare e consumare di meno.

Entro il 2050 i due terzi degli abitanti della Terra vivranno in agglomerati urbani. VERO O FALSO?

Risposta:VERO
Dall'aumento degli abitanti nelle città nasce la necessità sempre maggiore di creare centri urbani che rispettino i principi della sostenibilità.

CITTADINANZA

I dati ISTAT pongono tra i primi posti nell'utilizzo di orti urbani quale regione italiana?

a) Lombardia
b) Puglia
c) Veneto
d) Basilicata

Risposta: A
Al primo posto l'Emilia Romagna (704 mila metri quadrati), seguita dalla Lombardia (193 mila metri quadrati) e Toscana (170 mila). Le Marche contano un buon risultato (103 mila).

Nelle varie definizioni di "sviluppo sostenibile" si fa sempre riferimento a:

a) Inquinamento dell'ambiente
b) Crescita economica
c) Capacità di vivere in maniera dignitosa ed equa per tutti, per un'equa distribuzione delle risorse nel pianeta
d) Utilizzo di fonti di energia rinnovabili come quella solare ed eolica

Garantire a tutti gli abitanti del pianeta l'accesso alle risorse naturali e ad un'equa distribuzione della ricchezza, assicurando un lavoro soddisfacente e condizioni di vita dignitose per tutti. Predare meno piuttosto che "dare di piu"".

Risposta: C

Prova di velocità e concentrazione

In un minuto, senza fermarti mai devi istruire i tuoi compagni sul risparmio idrico domestico: pulizia corpo, lavaggio denti, bagno e doccia. Se sbagli, ricominci da capo.

Prova di velocità e concentrazione

In un minuto, senza fermarti mai devi elencare i 17 Goals dell'Agenda 2030.Se sbagli, ricominci da capo.

Anagrammiamo!

In un minuto, trova le parole corrispondenti al seguente anagramma (n.2 parole):

STUPISSE PELLI BOVINO

Risposta:
SVILUPPO SOSTENIBILE

Anagrammiamo!

In un minuto, trova le parole corrispondenti al seguente anagramma (n.2 parole):

TRUCIOLI IMPARANDO MA

Risposta:
RIDUCO LA MIA IMPRONTA

Fa rima con…

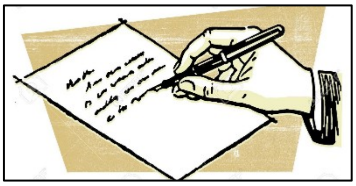
In un minuto, trova almeno 5 parole che facciano rima con DISUGUAGLIANZA:

Risposta:
Abbondanza, abbastanza, arroganza, assomiglianza, belligeranza, ambulanza…..

Continua tu la frase….

Completa le frasi riferite ad alcuni Goal dell'Agenda 2030: nella tua scelta?

a)…la fame
b) agire per il…
c) consumo e … responsabili
d) … sulla Terra
e) energia… e accessibile



Risposta:
a) sconfiggere
b) clima
c) produzione
d) vita
e) pulita

SFIDA TESTA A TESTA

Prova di velocità e concentrazione

In un minuto, senza fermarti mai devi istruire i tuoi compagni sul comportamento di un consumatore responsabile.

Anagrammiamo!

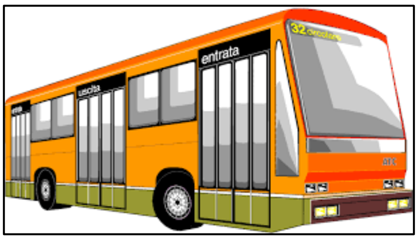
Qui sotto, trovi due anagrammi di DUE parole inglesi. Trova le parole.

GREENY, GIRENE

Risposta:
GREEN ENERGY

Utilizzare borracce anziché bottigliette di plastica: bere, lavare, riempire di nuovo.

Preferire mezzi pubblici, andare a piedi e in bici piuttosto che in macchina.



Uscendo dalle stanze, spegnere sempre la luce. Spegnere computer, portatili, TV se non utilizzati.

No aria condizionata e finestre aperte nello stesso momento: si spreca molta energia!

Plastica ed alluminio vanno nel sacchetto della differenziata, così come la carta! Non mischiare i diversi tipi di rifiuti!

Prima di riciclare, riusare!

MIMO INDIVIDUALE

Un consumatore consapevole legge sempre bene l'etichetta di quello che compra, per vedere ingredienti e provenienza.

Scegliere prodotti riutilizzabili o con materiale riciclato.

Trova il Goal corrispondente:

1. ABBATTERE
2. VEDERE
3. SUCCESSO
4. POTERE

RISPOSTA

Trova il Goal corrispondente:

1. RISTRETTEZZA
2. SCARSITA'
3. SUPERARE
4. CADERE

RISPOSTA

Trova il Goal corrispondente:

1. CENTRO
2. STARNUTO
3. TUA
4. ECONOMICO

RISPOSTA

Trova il Goal corrispondente:

1. GARANZIA
2. DARE
3. CONTROLLO
4. USO

RISPOSTA

Trova il Goal corrispondente:

1. ESSERE
2. PUNTEGGIO
3. UMANO
4. TESTO

RISPOSTA

Trova il Goal corrispondente:

1. PERSONALE
2. DEPURATA
3. NATURALE
4. LINDA

RISPOSTA

GHIGLIOTTINA

Trova il Goal corrispondente:

1. SQUADRA
2. SVILUPPO
3. ONESTO
4. CERCARE

RISPOSTA

Trova il Goal corrispondente:

1. ATTIVITA'
2. OPEROSITA'
3. RIVOLUZIONE
4. IMPIANTI

RISPOSTA


1 POVERTÀ ZERO
2 FAME ZERO
3 SALUTE E BENESSERE
5 UGUAGLIANZA DI GENERE
6 ACQUA PULITA E IGIENE
4 ISTRUZIONE DI QUALITÀ


4 ISTRUZIONE DI QUALITÀ
7 ENERGIA PULITA E ACCESSIBILE
16 PACE, GIUSTIZIA E ISTITUZIONI FORTI
9 INDUSTRIA, INNOVAZIONE E INFRASTRUTTURE
10 RIDURRE LE DISUGUAGLIANZE

Questionario docenti S-City Cardboard Game

Diffusione e gradimento attività "Gioco Sustainable City"

1. Genere

Contrassegna solo un ovale.

- M
- F

2. Età

Contrassegna solo un ovale.

- 30-35
- 36-40
- 41-46
- 47-52
- 53-58
- 59-65
- Opzione 7

3. Disciplina insegnata:

Seleziona tutte le voci applicabili.

- [ ] Matematica
- [ ] Scienze
- [ ] Italiano
- [ ] Geografia
- [ ] Tecnologia
- [ ] Altro

4. Da quanti anni insegna (sia da precario che di ruolo)

Contrassegna solo un ovale.

- 1-5
- 6-10
- 11-15
- 16-20
- Oltre 21

5. Conoscevo i temi trattati (Agenda 2030 e Sviluppo Sostenibile) prima dell'attività

Contrassegna solo un ovale.

- Si
- No

6. Se sì, in quale occasione ne è venuto/a a conoscenza?

____

7. Ne ha parlato in classe? Se sì, in relazione a quale/i argomento/i?

____

8. Se ne ha parlato in classe, ha fatto riferimento anche ad altre discipline, visto che gli argomenti dell'Agenda 2030 sono multidisciplinari?

Contrassegna solo un ovale.

- Si
- No

9. E' interessato/a ad approfondire queste tematiche

Contrassegna solo un ovale.

- Sì
- No

10. Ha apprezzato questa modalità didattica basata sul gioco per trattare i temi dell'Agenda 2030

Contrassegna solo un ovale.

- 1=per niente d'accordo
- 2= poco d'accordo
- 3= d'accordo
- 4= molto d'accordo
- 5= del tutto d'accordo

11. Gli alunni della sua classe si sono dimostrati interessati agli argomenti trattati nel gioco

Contrassegna solo un ovale.

- 1=per niente d'accordo
- 2= poco d'accordo
- 3= d'accordo
- 4= molto d'accordo
- 5= del tutto d'accordo

12. Gli alunni della sua classe si sono dimostrati coinvolti nell'attività, grazie alla strategia del gioco

Contrassegna solo un ovale.

- 1=per niente d'accordo
- 2= poco d'accordo
- 3= d'accordo
- 4= molto d'accordo
- 5= del tutto d'accordo

13. Questo approccio didattico può essere utile per coinvolgere maggiormente gli alunni diversamente abili

Contrassegna solo un ovale.

- 1=per niente d'accordo
- 2=poco d'accordo
- 3= d'accordo
- 4= molto d'accordo
- 5= del tutto d'accordo

14. Questo approccio didattico può essere utile per coinvolgere maggiormente gli alunni con difficoltà di apprendimento

Contrassegna solo un ovale.

- 1= per niente d'accordo
- 2= poco d'accordo
- 3= d'accordo
- 4= molto d'accordo
- 5= del tutto d'accordo

15. Il gioco S-city, se proposto più volte durante l'anno scolastico, può essere uno strumento efficace per far conoscere agli alunni stili di vita sostenibili

Contrassegna solo un ovale.

- 1=per niente d'accordo
- 2=poco d'accordo
- 3= d'accordo
- 4= molto d'accordo
- 5= del tutto d'accordo

16. Il gioco S-city, se proposto più volte durante l'anno scolastico, può divenire uno strumento efficace per l'adozione concreta di semplici buone pratiche da parte degli alunni

Contrassegna solo un ovale.

- 1=per niente d'accordo
- 2= poco d'accordo
- 3= d'accordo
- 4= molto d'accordo
- 5= del tutto d'accordo

17. I punti di debolezza del gioco sono

18. I punti di forza del gioco sono

19. In base alla sua materia, quali domande proporrebbe per il gioco attinenti alle tematiche dell'Agenda 2030?

Questionario alunni S-City cardboard Game

Diffusione e gradimento attività "Gioco Sustainable City"

1. Genere

   Contrassegna solo un ovale.

   - M
   - F

2. Conoscevo i temi trattati (Agenda 2030 e Sviluppo Sostenibile) prima dell'attività

   Contrassegna solo un ovale.

   - Si
   - No

3. Se sì, con insegnanti di quale/i materia/e ne avete parlato in classe? (puoi mettere anche più di una risposta)

   Seleziona tutte le voci applicabili.

   - [ ] Italiano, storia
   - [ ] Geografia
   - [ ] Matematica
   - [ ] Scienze
   - [ ] Tecnologia
   - [ ] Altro............

4. L'argomento del gioco ti ha interessato?

Contrassegna solo un ovale.

- 1= per niente d'accordo
- 2=poco d'accordo
- 3=d'accordo
- 4=molto d'accordo
- 5= del tutto d'accordo

5. L'attività del gioco da tavolo in classe mi è piaciuta

Contrassegna solo un ovale.

- 1=per niente d'accordo
- 2=poco d'accordo
- 3=d'accordo
- 4=molto d'accordo
- 5= del tutto d'accordo

6. Mi piacerebbe ripetere ogni tanto in classe questo gioco con insegnanti delle diverse materie coinvolte nelle domande

Contrassegna solo un ovale.

- 1=per niente d'accordo
- 2=poco d'accordo
- 3= d'accordo
- 4= molto d'accordo
- 5= del tutto d'accordo

7. Mi piacerebbe affrontare in classe anche altri argomenti sempre con lo stesso metodo del gioco da tavolo a squadre

Contrassegna solo un ovale.

- 1=per niente d'accordo
- 2= poco d'accordo
- 3= d'accordo
- 4= molto d'accordo
- 5= del tutto d'accordo

8. Scrivi una cosa che ti è piaciuta particolarmente di questa attività

9. Scrivi una cosa che non ti è piaciuta di questa attività e che cambieresti

The final challenge-SDGs campaigns
SDG 3

Salute e Benessere

perché è importante per sopravvivere

e perché è importante curarsi

IL GOAL TRE E' MOLTO IMPORTANTE PER LE PERSONE PERCHE' SI OCCUPA DEL BENESSERE E DELLA SALUTE DELLE PERSONE. VA RISPETTATO

The final challenge-SDGs campaigns SDG 15

Sustainable City Game - Questionario docenti

Questionario post-attività - Sustainability City Game - Docenti

*Campo obbligatorio

1. Genere

Contrassegna solo un ovale.

- Donna
- Uomo

2. Età

Contrassegna solo un ovale.

- meno di 30
- 30-39
- 40-49
- 50-59
- 60 ed oltre

3. In che ordine di scuola insegna?

Contrassegna solo un ovale.

- Primaria
- Secondaria di primo grado
- Secondaria di secondo grado

4. Disciplina insegnata *

____

5. Anni di servizio nella scuola *

Contrassegna solo un ovale.

- meno di 5
- 6-10
- 11-15
- 16-20
- 21-25
- 26-30
- oltre 30

6. A suo parere, quando è opportuno giocare a S City game? *

Contrassegna solo un ovale.

- Prima di affrontare gli argomenti di sostenibilità in classe, per incuriosire gli studenti sulla tematica
- Dopo aver già affrontato gli argomenti di sostenibilità in classe, come attività finale di riepilogo
- Nell'ambito di un progetto specifico sulla sostenibilità, come attività complementare
- Altro: ________________

7. Secondo te qual è il numero di giocatori ottimale? *

Contrassegna solo un ovale.

- 4
- 5
- 6
- 7
- 8
- Altro: ________________

8. Risponda alle seguenti affermazioni *

Contrassegna solo un ovale per riga.

	Per niente d'accordo	Poco d'accordo	Incerto	Molto d'accordo	Del tutto d'accordo
Ritengo interessante ed efficace per gli alunni affrontare le tematiche della sostenibilità attraverso il gioco S-City Game					
Le regole del gioco sono facili da applicare					
Il gioco ha molti tempi morti					
La grafica del gioco è accattivante					
Le domande del gioco sono troppo semplici per il mio livello di scuola					
Le domande del gioco sono troppo difficili per il livello di scuola					
Non ho avuto difficoltà a leggere il valore delle facce dei dadi					
trovo difficile inquadrare il tabellone e i pannelli					

9. Le sono piaciute queste prove del gioco? *

Contrassegna solo un ovale per riga.

	non so (non l'ho ancora provata)	per niente d'accordo	poco d'accordo	incerto	molto d'accordo	del tutto d'accordo
Domande disciplinari individuali						
la sfida (giochi online)						
Guess the action (indovina l'azione)						
la ghigliottina (4 indizi per 1 obiettivo)						
la prigione						
Il domandone						

10. Suggerimenti per migliorare alcune prove del gioco S-City Game *

11. Come giudica la partecipazione degli alunni alle attività proposte? *

12. Dopo l'attività del gioco ha notato negli alunni un maggiore interesse per gli argomenti della sostenibilità ambientale? *

13. Ritiene questa attività efficace nell'ambito della DAD? *

Post-attività Sustainability City Virtual Game

Questionario post-attività - Sustainability City Game

*Campo obbligatorio

1. Sei... *

Contrassegna solo un ovale.

- un ragazzo
- una ragazza

2. Frequenti la classe... *

Contrassegna solo un ovale.

- classe 1 - Secondaria di secondo grado
- classe 2 - Secondaria di secondo grado
- classe 3 - Secondaria di secondo grado
- Altro: ____________________

3. sezione *

____

4. Scuola *

____

5. Secondo te, quali sono i cinque problemi più urgenti che si dovrebbero risolvere con la maggiore priorità? *

Seleziona tutte le voci applicabili.

- [ ] Guerre civili in alcuni Paesi del mondo
- [ ] Fame e povertà nel mondo
- [ ] Carenza di acqua potabile
- [ ] Cambiamenti climatici
- [ ] Crescita continua della popolazione mondiale
- [ ] Sovrasfruttamento delle risorse naturali
- [ ] Assenza di connessione wi-fi libera in ogni città
- [ ] Scomparsa di diverse specie animali e vegetali
- [ ] Concentrazione della ricchezza nelle mani di pochi
- [ ] Perdita di profitto delle imprese

Altro: [ ] ______________________

6. Metti in ordine le seguenti azioni, indicando con i numeri più bassi quelle a cui dare priorità (che vanno fatte per prime) *

Contrassegna solo un ovale per riga.

	1	2	3	4
Riciclare	⬭	⬭	⬭	⬭
Ridurre (evitare lo spreco)	⬭	⬭	⬭	⬭
Riusare (allungare la vita di un prodotto)	⬭	⬭	⬭	⬭
Riparare	⬭	⬭	⬭	⬭

7. Quali secondo te, sono delle risorse (più di una risposta possibile) *

Seleziona tutte le voci applicabili.

- [ ] Acqua
- [ ] Rifiuti
- [ ] Un vecchio PC
- [ ] Scarti alimentari
- [ ] Gas di scarico delle auto
- [ ] Suolo
- [ ] Minerali
- [ ] Il mio cellulare rotto
- [ ] Vento
- [ ] Calore interno alla Terra

8. Adesso si sente molto parlare di "sviluppo sostenibile". Secondo il tuo parere, può significare: *

Contrassegna solo un ovale.

- sviluppo che si sostiene con un aumento della ricchezza
- sviluppo che soddisfa tutte le nostre esigenze
- sviluppo che soddisfa le nostre esigenze e quelle delle generazioni future
- sviluppo che salvaguardia l'ambiente

9. Indica qual è il livello attuale di anidride carbonica nell'aria *

Contrassegna solo un ovale.

- 250 ppm
- 410 ppm
- 320 ppm
- 380 ppm

10. L'aumento di temperatura globale nel mondo rispetto all'era pre-industriale è di circa *

Contrassegna solo un ovale.

- 0 °C
- 0.5 °C
- 1 °C
- 1.5 °C

11. L'impronta idrica, secondo te, può significare... *

Contrassegna solo un ovale.

- Dilavamento del suolo per forti piogge
- Consumo di acqua necessaria per produrre oggetti o cibo
- litri di acqua consumati nelle attività domestiche ed industriali
- L'acqua necessaria per l'agricoltura

12. L'impronta di carbonio di un prodotto o di un servizio (es. trasporto pubblico) misura... *

Contrassegna solo un ovale.

- La quantità di energia necessaria per produrre quel prodotto o servizio
- La quantità di gas serra emessi, soprattutto anidride carbonica, per produrre quel prodotto o servizio
- La quantità di carbone necessaria per produrre quel prodotto o servizio
- la quantità di alberi necessari per assorbire l'anidride carbonica emessa per produrre quel prodotto / servizio

13. Le dimensioni dello sviluppo sostenibile, secondo quanto emerge dai Goal dell'Agenda, 2030 sono:

Contrassegna solo un ovale.

- economica, sociale, politica
- ambientale, economica, sociale
- sociale ed ambientale
- ambientale ed economica

14. I Goal dell'Agenda 2030 sono:

Contrassegna solo un ovale per riga.

	fortemente in disaccordo	in disaccordo	incerto	d'accordo	fortemente d'accordo
interconnessi e interdipendenti l'uno dall'altro					
articolati in 169 targets					
finalizzati a raggiungere la pace universale					
inseriti in un programma che riguarda persone, pianeta, governance, sviluppo economico					
condivisi da alcuni Paesi membri dell'ONU					

15. Metti una crocetta sui 5 principali obiettivi di sviluppo sostenibile che secondo te dovrebbero essere raggiunti nel campo della sostenibilità urbana e cittadina (non piu' di 5 obiettivi) *

Seleziona tutte le voci applicabili.

- [ ] 1
- [ ] 2
- [ ] 3
- [ ] 4
- [ ] 5
- [ ] 6
- [ ] 7
- [ ] 8
- [ ] 9
- [ ] 10
- [ ] 11
- [ ] 12
- [ ] 13
- [ ] 14
- [ ] 15
- [ ] 16
- [ ] 17

16. A tuo parere, quando è opportuno giocare a S City game? *

Contrassegna solo un ovale.

- Prima di affrontare gli argomenti di sostenibilità in classe, per incuriosire gli studenti sulla tematica
- Dopo aver già affrontato gli argomenti di sostenibilità in classe, come attività finale di riepilogo
- Nell'ambito di un progetto specifico sulla sostenibilità, come attività complementare
- Altro: ______

17. Secondo te qual è il numero di giocatori ottimale? *

Contrassegna solo un ovale.

- 4
- 5
- 6
- 7
- 8
- Altro: ______

18. Rispondi alle seguenti affermazioni *

Contrassegna solo un ovale per riga.

	Per niente d'accordo	Poco d'accordo	Incerto	Molto d'accordo	Del tutto d'accordo
Ritengo interessante ed efficace affrontare le tematiche della sostenibilità attraverso il gioco S-City Game					
Le regole del gioco sono facili da applicare					
Il gioco ha molti tempi morti					
La grafica del gioco è accattivante					
Le domande del gioco sono troppo semplici per il mio livello di scuola					
Le domande del gioco sono troppo difficili per il livello di scuola					
Non ho avuto difficoltà a leggere il valore delle facce dei dadi					

19. Ti sono piaciute queste prove del gioco? *

Contrassegna solo un ovale per riga.

	non so (non l'ho ancora provata)	per niente d'accordo	poco d'accordo	incerto	molto d'accordo	del tutto d'accordo
Domande disciplinari individuali	⬭	⬭	⬭	⬭	⬭	⬭
la sfida (giochi online)	⬭	⬭	⬭	⬭	⬭	⬭
Guess the action (indovina l'azione)	⬭	⬭	⬭	⬭	⬭	⬭
la ghigliottina	⬭	⬭	⬭	⬭	⬭	⬭
la prigione	⬭	⬭	⬭	⬭	⬭	⬭
Il domandone	⬭	⬭	⬭	⬭	⬭	⬭

20. Suggerimenti per migliorare alcune prove del gioco S-City Game *