Universidad de Oviedo
Facultad de Formación del Profesorado y Educación

MICROPLASTICS AND THEIR WAY INTO OUR PRIMARY EDUCATION SYSTEM

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GRADO EN MAGISTERIO PRIMARIA

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Trabajo de fin de grado. Grado en maestro de educación primaria.

Abstract

Due to a recent, overwhelming and non-biodegradable plastic contamination outburst, we are currently as vulnerable as ever to microplastics. These are diminutive plastic particles ubiquitously identified throughout terrestrial, aquatic, and human compartments and which have become major pollutants. We have reached an inflexion point where the toxicity of plastic debris is exponentially growing as the rate of commercial plastic production increases. Our welfare as a species is greatly jeopardized and immediate, significant measures must be implemented as soon as possible.
The present bachelor’s thesis focuses in synthesizing the recent literature regarding microplastic pollution, briefly tackling each area of influence to further craft a didactic program suitable to bring this emerging topic into our educational institutions. Following the recently established law of education in Spain (LOMLOE), one of the key aspects of education is to ensure that young generations of students are aware of 21st century global threats that will certainly have to be faced in a foreseeable future. Hence, this dissertation offers a didactic framework as a guide to insert the topic of microplastics within the Spanish curricula, offering interactive and engaging educational activities that contribute to a further understanding of the situation. In parallel, this topic aims to open a new space for debate within school’s boundaries to increase the interest and participation of the students on the matter.

Keywords: Contamination; Global threat; Human health; Toxicity; Didactic program; LOMLOE; Environment.

Resumen

Debido a un reciente y abrumador estallido de contaminación plástica no biodegradable, actualmente somos más vulnerables que nunca a los microplásticos. Los microplásticos se pueden definir como pequeñas partículas de plástico identificadas de forma ubicua en todos los compartimentos terrestres, acuáticos y humanos, convirtiéndose en grandes contaminantes. Hemos llegado a un punto de inflexión en el que la toxicidad de los residuos plásticos crece exponencialmente a medida que aumenta el ritmo de su producción comercial. Nuestro bienestar como especie está en grave peligro y deben aplicarse medidas urgentes y de gran calado lo antes posible.
Este trabajo se centra en sintetizar la literatura reciente sobre la contaminación por microplásticos, abordando brevemente cada área de influencia. El objetivo último es elaborar un programa didáctico adecuado para alumnos de educación Primaria, y que sirva para introducir este tema emergente en nuestras instituciones educativas. Siguiendo la recientemente establecida ley de educación en España (LOMLOE), uno de los aspectos clave de la educación es asegurar que las generaciones jóvenes de estudiantes sean conscientes de las amenazas globales del siglo XXI a las que, sin duda, tendrán que enfrentarse en un futuro próximo. Por lo tanto, este proyecto ofrece un marco didáctico exhaustivo que sirve como guía para insertar el tema de los microplásticos contextualizado dentro del currículo español, ofreciendo actividades educativas interactivas que contribuyan a una mayor comprensión de la situación y, al mismo tiempo, abran un nuevo espacio de debate dentro de los límites de la escuela para aumentar el interés y la participación de los estudiantes en la materia.

Palabras clave: Contaminación, Amenaza global, Riesgo, Toxicidad, Programa didáctico, LOMLOE, Medio ambiente.

1. INTRODUCTION

1.1 CONTEXT AND JUSTIFICATION

Society is certainly in a state of flux. Human actions are dramatically changing our planet. Earth's ecosystems have been exposed to critically negative impacts since the 17th century after the industrial revolution. Nowadays, approximately 75% of worldwide ice-free land area has been remarkably altered. In fact, more than 85% of wetlands have been lost, and the oceans are experiencing significant threats such as pollution, acidification, and overfishing (WWF, 2020). Roughly 28% of species around the world are being severely threatened due to human actions such as habitat degradation, hunting, and plastic pollution (Croxall et al., 2012; Roman et al., 2020; Žydelis et al., 2013). The latter has been traditionally neglected or ignored by all human civilizations since plastic began to be massively used during the 20th century. However, since the last decade its impact on ecosystems and human health is gathering more attention among the scientific community, with an impressive increase of scientific papers published on this issue during the last ten years (Figure 1).

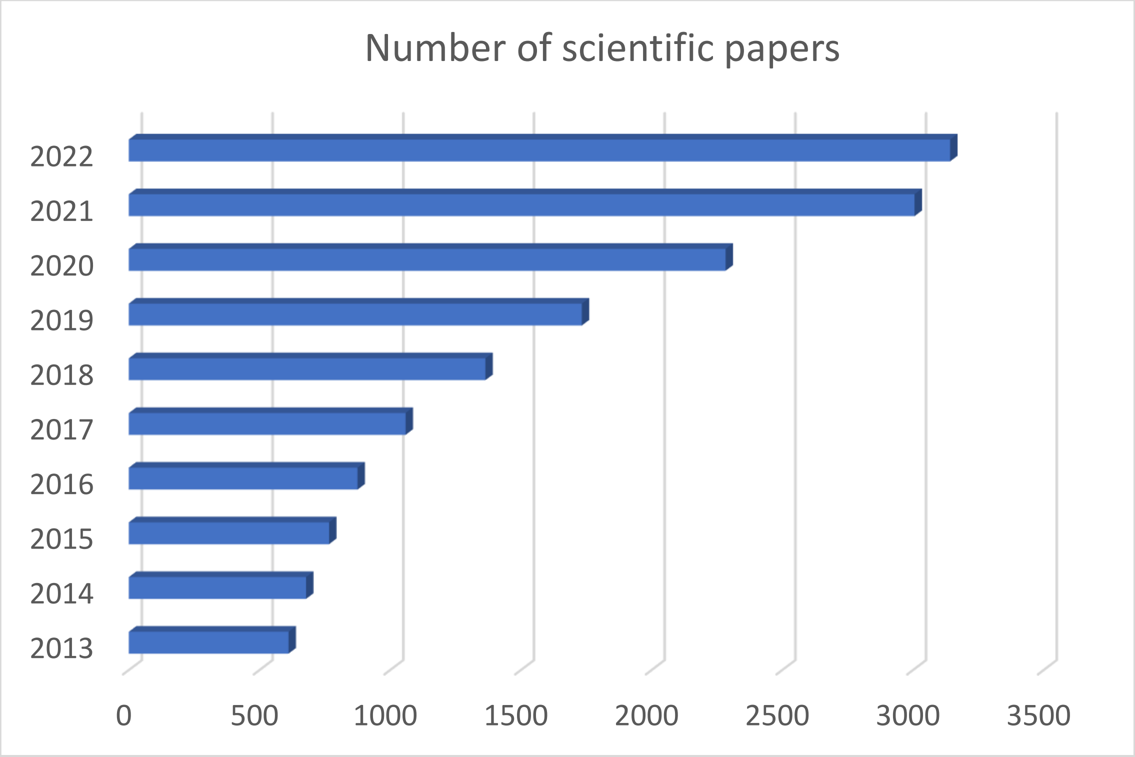

Fig. 1. Number of scientific papers published last 10 years. Source: Web of Science, using "plastic" and "environment" as key words.

Over the last seventy years, our societies have become exponentially and carelessly dependent on plastics. Between the 1950s and 2015, the global annual growth rate of plastic production reached the alarming figure of 8.4% (Geyer et al., 2017). Developing and emerging countries are now also adopting the popular production of plastic *en masse* (Lwanga et al., 2017), thus aggravating the outbreak of global plastic manufacture and consumption. We have reached the point in time where the annual rate of plastic weight produced has recently exceeded the annual weight of carbon emitted to the atmosphere (Hale et al., 2020).

Our exponential reliance on plastic commercial production over the previous decades is taking a toll, not just on our environmental welfare but also on our own health. The low production costs, versatility, corrosion resistance and lightweight have hugely fueled the global demand. Despite, the impact of plastic debris on marine fauna was first investigated back in the 1960s (Kenyon and Kridler, 1969), the actual amounts of plastics in environmental compartments (terrestrial, marine, freshwater, and atmospheric) and their ecological significance are not well known yet. It is because only recently begun to receive the attention that the topic deserves and consequently there are a limited number of methods for collecting and analyzing data. (Hale et al., 2020).

Most of the plastic-debris-related papers published so far conclude that we are facing a serious global health concern. For instance, Villarrubia Gómez et al., (2018) stated that marine plastic contamination is "irreversible and globally all-pervasive". It therefore meets two of the three conditions needed for the problem to be defined as a chemical pollution planetary boundary threat. The third condition to be met is a demonstrated widespread ecological disruption. Research on the requirements and standards needed to prove this mentioned disruption is in its infancy. However, it is predictable that they will progressively increase due to the interest shown by the developed countries in understanding the impact of plastics on the ecosystem services and, ultimately, on human welfare. Finally, some researchers such as Koelmans et al., (2017) suggest that we are in an inflexion point and we must move from speculation into action. Consequently, he already proposed a framework for evaluating toxicological risks of microplastics.

What are microplastics?

Microplastics are small plastic particles ranging from less than 0.5 mm to 5,000 μm. They can be classified as primary (those manufactured specifically for their qualities), secondary (originating from the degradation of larger plastics), or tertiary (further degraded microplastics), although this last group is not always considered as they've been often grouped with secondary microplastics as a whole (Carbery et al., 2018). Further details on microplastics' composition, arrangement and classification will be described in the theoretical frame of this project.

As critical and significant as the issue of microplastics in our oceans really is, the reality is even more complex and concerning. A large proportion of waste plastics are discarded in landfills, incinerated, or recycled, yet it is mostly mismanaged and inevitably makes its way into the natural environment (Hale et al., 2020). As a result, microplastics are everywhere, and human ingestion through food and water is the major route of exposure in humans (Toussaint et al., 2019), adding inhalation (airborne microplastics) and dermal contact. We have already reached a point where different types of microplastics with dissimilar sizes and categories regularly appear in human stool samples (Schwabl et al., 2019)

1.2 DISERTATION'S PURPOSE AND STRUCTURE

Microplastics are an ongoing environmental problem and, unquestionably, a global threat in the 21st century. It is a complex issue that must be addressed within our educational institutions. As we are discussing an emerging field of research, which is up-to-date with present scientific concerns, it is undoubtedly necessary for younger generations to learn about their environmental, health and scientific implications. To achieve this, the first step of this project is to carry out an exhaustive bibliographical analysis on our current situation regarding global microplastics use and the consequences of this harmful management. After this information is recollected, evaluated, and taken into consideration, a didactic approach will be crafted to promote and foster a favorable outlook towards this threatening worldwide issue in our contemporary educational system. In other terms, my dissertation aims to be a beacon of awareness and representation, while at the same time serving as a call of action towards young generations, who will have to deal with these problems in a foreseeable future. If we are able to build meaningful and significant educational activities which tackle the root of the problem, we will start creating a foundation of active citizens that will participate in the protection of biodiversity by demanding change and prosperity.

This dissertation can also serve as a call of action for making the teaching of microplastics explicit in the current curricula but at the same time, to move beyond basic understanding of what they are. Thus, I will design meaningful and significant didactic activities, with the final aim of making students aware of the problem and helping them to build a critical view about the use of plastics in their routines. We can seize the opportunity that microplastics are an interdisciplinary topic of interest, which involves various scientific fields of knowledge such as chemistry, biology, and environmental sciences. Students can grasp knowledge out of all of them and observe how they intersect.

All of this said, it is emphasized the importance of periodical curriculum modifications to promote an education that is up to date with the latest scientific milestones. Even if the didactic application proposed is specified and contextualized within the guidelines of the Spanish curriculum, it still can act as a template for alternative uses in other geographical regions or cultural atmospheres.

1.3 RESOURCES, METHODOLOGY USED AND RESULTS OBTAINED

In order to conduct the theoretical research to base my didactic proposal on, first, it was necessary to use information-gathering tools to collect reliable scientific knowledge related to the microplastics' crisis with ease and efficacy. These mentioned tools were two main platforms: "Scopus" and "Google Scholar".

The way to work with "Scopus" was by using key words in the search bar to reduce the range of scientific articles and magazines that were displayed. I started with the evident key word "microplastics", which showed me more than 13 681 research papers tackling this topic. However, if I added to the filter the key words "impact" and "ecosystems", the web displayed 7993 documents. By adding additional key words such as "pollution", "soil" "ocean" "human health", "exposure" and "animals" to further narrow down the search I ended up with 911 documents, a considerably manageable amount which was then easier to handle and work with. I selected a few articles to start my reading process and worked with their references.

We can consider therefore that adding key words aided me to search for secondary resources of information that truly focused and emphasized on the issue that I was tackling. I tried to concentrate on general scientific reviews as these papers gave thorough insight into the matter while not being overly specific in technical terms.

This method of information gathering was crucial to save lots of time, as I was able to cut thousands of research papers that were not fully linked to my subject of matter. Some of those that remained after using key words as a filtering mechanism were the ones I started reading and used as base to my theoretical frame.

The primordial disadvantage of using “Scopus” as a research tool was that a subscription is needed for its use. Fortunately, the University of Oviedo is a public research institution with access to such a platform. However, I had to be connected to the Wi-Fi of the mentioned institution and consequently, I couldn’t work with it at home.

On the other hand, “Google Scholar” is a free, open access website that allowed me to complete further research on the matter at home. Even though with this research tool I couldn’t filter the scientific journals with the precision characterized by “Scopus”, it was more than enough to find interesting and pertinent papers by typing in the search bar concrete compartments that I wanted to find information about. It also helped with finding referenced articles from other scientific papers which could be of use. The articles found in Google Scholar truly helped to complete, strengthen and deepen the research into the current literature of microplastics.

2. THEORETICAL FRAMEWORK

2.1 PLASTICS IN NATURE AND MICROPLASTICS DEFINITION

It is often assumed that all plastic derivatives are compositionally identical and consequently, have the same impact and interaction on the environment. However, this is not the case. In order to comprehend the behavior and consequences that microplastics bring to our reality, we must first define their composition, physical forms, uses, transport, and fragmentation.

Plastics have been historically crafted from diverse sources, which include fossil fuels (like crude oil and natural gas) and renewable materials (such as starch, vegetable oils and sugarcane) (Kumar Naik et al., 2022). Microplastics, as mentioned earlier in this entry, are small plastic pieces which measure less than 5 mm long and have been recently identified in an extensive range of environments such as soil, freshwater, ocean and organisms (He et al., 2018).

Identifying and classifying microplastics remains a scientific challenge. Their variability in physical shape, chemical composition, size and texture makes them difficult to identify and quantify. In addition, as microplastics can be found on complex elements such as water, sediments and biological tissues, sorting them out is even more demanding. In fact, microplastic complexity is similar to that of naturally occurring organic matter in terms of their composition and structure (Hoellein et al., 2019).

Even though the characterization of microplastics is unquestionably problematic, there's a commonly used classification scheme for these plastic structures which considers their origin, mode of generation, size and production.

Microplastics intentionally manufactured for particular reasons are termed primary microplastics. These include microbeads (found in personal care products, cleaning agents and paints, among others) and industrial abrasives (Hale et al., 2020). Microbeads' consequences on the environment are of such magnitude that in the United States, the "Microbeads Free Waters Act of 2015" was put in place to ban microbeads use from personal care products (McDevitt et al., 2017), yet not from non-rinse off (*e.g.*, sunscreen and cosmetic makeup) or industrial applications. Alike regulations have been promulgated in other countries like Canada, France and Italy among others. Unfortunately, there is no single European law dealing with microplastics in a comprehensive manner.

Among the primary microplastics, the most manufactured types are "polycarbonates (PC), polypropylene (PP), polyvinyl chloride (PVC), polyethylene (PE), polyurethane (PU) and polystyrene" (Li et al., 2016; Muhammad Ubaid Ali et al., 2021).

On the other hand, secondary microplastics are defined to those formed by the fragmentation of larger plastics during usage (for instance, from the erosion of tires) or after disposal (Hale et al., 2020). These microplastics can be formed by degradation and the level of the same depends on diverting factors such as the type of polymer, age and environmental conditions like temperature, irradiation, weathering and pH (Akbay and Ozdemir, 2016).

Microplastics fragment into even smaller debris over time, eventually becoming nanoplastics (<1μm; Lambert&Wagner, 2016; Hartmann et al., 2019). These are sometimes denominated tertiary microplastics, as they involve a further process of degradation.

Agricultural activities like plastic mulching and packing materials hugely contaminate the soils with plastic particles (Naik et al., 2022). Hence, agricultural soils are sinks for microplastic pollution which negatively conditions their own biostructure and thus, the organisms that live in it. Microplastics present on soil surfaces eventually leach out to water bodies. In the surface of these water bodies, microplastics weather down and sink, ultimately being ingested by organisms and redistributed by flow currents (Hale et al., 2020). Plastic particles smaller than 20 μm can penetrate cell membranes, aggravating the consequences. Exposure to plastics conditions "feeding, metabolic processes, reproduction and behavior". Human ingestion of contaminated food is also a matter of concern. Overall, microplastics are the new plague of the 21st century.

Based on the available literature, and as was mentioned earlier in the proposal of this dissertation, the present bachelor's thesis will provide a thorough, comprehensive yet concise review of the global emission and pollution of microplastics throughout all the biotic (living organisms) and abiotic (water, soil, and air) compartments (Figure 2). This division will be key to then create didactic activities that can tackle all scenarios of influence.

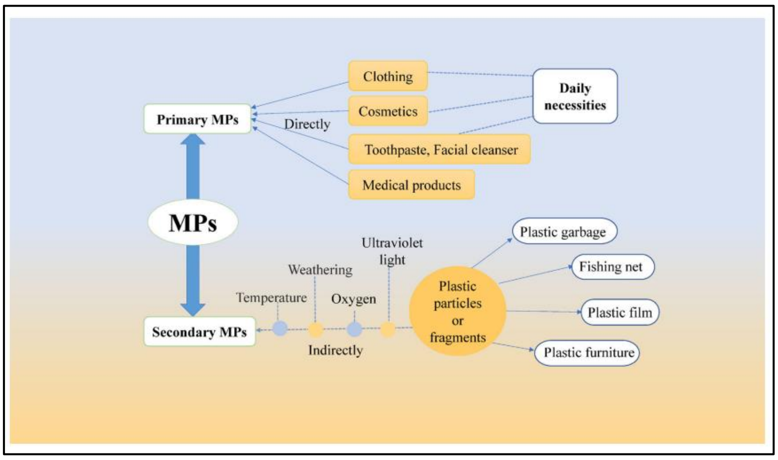

Fig. 2. Classification and origin of primary and secondary microplastics found everywhere. Source: FShttps://agupubs.onlinelibrary.wiley.com/doi/epdf/10.1029/2018JC014719E-21015-SQH 1..14 (hep.com.cn)

2.2 MICROPLASTICS IN THE OCEANIC AND RIVER COMPARTMENT

In recent years, marine litter has certainly become a concerning matter within the scientific community (Schnurr et al., 2018). Even though direct release of litter to the sea happens with marine-related activities such as fishing or tourism on cruise ships, literature on the origin of marine waste has put on emphasis on terrestrial sources as main culprits of marine pollution (Jambeck et al., 2015; Schmidt et al., 2017).

Plastic debris enters the aquatic environment as "trash, litter and industrial discharge" and is then worldwide transported by winds and currents (Smith et al., 2018). Nets, lines, floats and traps may also contain plastics and synthetic fibers, and even if they are intentionally crafted and designed to resist or slow down erosion, they degrade over time (Hale et al., 2020). Due to the propensity to degrade and fragment when used (Barnes et al., 2009), these unwanted plastic materials have magnified ocean pollution substantially.

Microplastics have been reported to be detected in the global oceanic environment, including in the North Atlantic, South Atlantic, South Indian, North Pacific, South Pacific and even in polar marine environments like Antarctic and Arctic waters (Eriksen et al., 2014; Sharma and Chatterjee, 2017). In fact, it was estimated that every year, about 4.8–12.7 million tons of plastic waste ends up in the oceans, and eventually, these plastic residues create around 5.25 trillion floating microplastics (Eriksen et al., 2014; Jambeck et al., 2015). To further demonstrate the potential significance of this situation, Isobe and other researchers in 2019 predicted that the weight of microplastics found around the Pacific Ocean would double by 2030 and quadrupole by 2060.

Now that the magnitude of the problem has been explicitly discussed, what consequences does this microplastic contamination have on the oceanic ecosystems? Many studies agree that the microplastics present in ocean ecosystems would be easily ingested by marine creatures due to their small size (Sharma and Chatterjee, 2017). The motivation behind ingesting these certainly not nutritious compounds reside in the combination of accidental ingestion and reaction to sensory cues (such as color and shape or tactile, Schuyler et al., 2014), yet it depends mostly on species and life stage (Hale et al., 2020). However, the presence of microplastics has been detected from small aquatic biota such as plankton and shellfish, to whales and sharks. As a matter of fact, a study lead by Shirel Kahane-Rapport in 2022, a renowned researcher from the universities of California and Standford, concluded that blue whales can consume up to ten million microplastic particles daily, fin whales between three and ten million and humpback whales up to four million when being fed by krill (Kahane-Rapport et al., 2022).

The ingestion of microplastics could cause many different health implications due to their toxicity. These health risks include reproductive complications, obstruction of digestive tract, reduced growth rate, and false satiation (Sutton et al., 2016). In addition, it can also cause behavioral changes, a modified immune response to stimulus and, eventually, it could lead to the death of millions of marine animals (Denuncio et al., 2011). Mattsson et al., (2017) reported that nanoplastic particles reduced the survival of zooplankton negatively altering trophic cascades.

The toxicity of microplastics in cells is largely triggered by oxidative stress reaction (Lee et al., 2013; Cole et al., 2015; Jeong et al., 2016), which is an "imbalance between production and accumulation of oxygen reactive species (ROS) in cells and tissues and the ability of a biological system to detoxify these reactive products." (Pizzino et al., 2017). This oxidative stress is what leads to cell damage and reduction in growth rate and reproductive capacity.

Much has been studied about microplastic pollution and its dreadful consequences in the marine environment, yet less attention has been placed on streams and rivers, despite they seem to be the main transition sources of microplastics to oceans. Lebreton and various researchers (2017) reported that every year, 1.15 to 2.41 million tons of plastics are discharged into the oceans via estuaries that are fed by rivers. This release of plastic debris is the consequence of surface runoff and atmospheric deposition, which transfers microplastics into freshwater systems. Eventually, these toxic materials move downstream and enter estuaries and coastal areas (Figure 3).

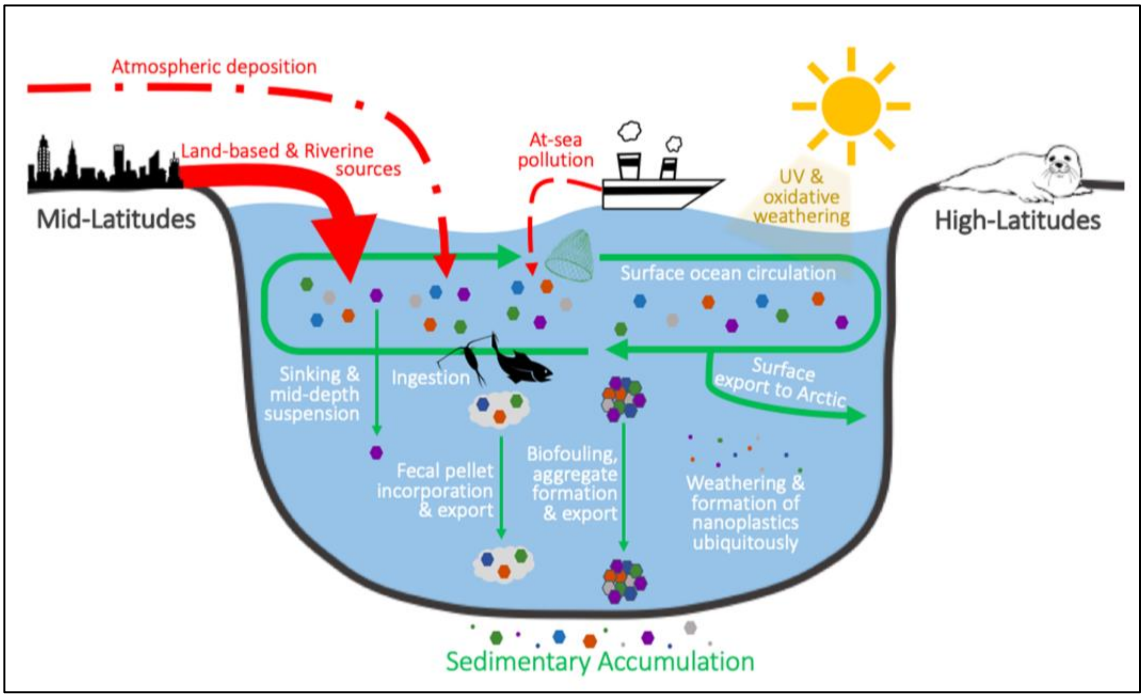

Fig. 3. Global ocean distribution of microplastics. Source: https://agupubs.onlinelibrary.wiley.com/doi/epdf/10.1029/2018JC014719

The media has drawn attention to the "Great Pacific Garbage Patch", which is a vast area of floating trash in the Pacific Ocean that is reported to be more than twice the size of the state of Texas (>1,400,000 km^2). According to a study by Lebreton (2018), it was estimated that 45,000 and 129,000 tons of plastic conformed that floating litter patch, with lost fishing nets accounting for 46% of that weight and microplastics consisting of 8%. However, these already eroded fishing nets will eventually wear down even further and degrade into smaller particles, consequently forming secondary microplastics. These fragments of plastic can also obstruct natural formations such as reefs, causing additional damage to marine wildlife.

If our production systems and way of living keep progressively relying on plastics, combined with a predictable growth in human population, we will likely face a consistent and significant rise in the concentration of microplastics in both the deep sea and shallow marine environments, which ultimately could increase the chances of these poisonous microplastics causing harmful effects.

2.3 MICROPLASTICS IN THE TERRESTIAL ECOSYSTEMS

While historically most scientific research and investigation focuses on the impact microplastics have on the marine environment (Cole et al., 2011), microplastic pollution in the soil has been overlooked and is now currently a subject of study by a plethora of scientists.

Unquestionably, soil is one of the most crucial resources on Earth, being the location of abundant ecosystems where plenty of organisms live and humans get uncountable primary resources from. Nevertheless, soil has become the predominant repository of microplastics. In fact, the scale of microplastic contamination in terrestrial compartments could be three to twenty-four times higher than that of the oceans, partly due to the "intensive application of sewage sludge and biosolids to farmlands" (Nizzetto et al., 2016; Wang et al., 2020). Indeed, many popular agricultural activities such as the already mentioned plastic mulching (used to control soil temperature and moisture), soil amendment application and fertilizer coatings, added to human activities like littering and sewage irrigation, perpetuate microplastic pollution in soils (Kumar Naik et al., 2022). The plastic materials used in these operations gradually transform into smaller residues, which ultimately degrades them into microplastics. This degradation, as mentioned earlier, is accelerated by the influence of certain biological, physical and chemical processes such as: ultraviolet radiations from the sun, water and/or air erosion, and even, due to earthworm activity (Wright and Kelly, 2017).

A study carried out by Kumar Naik and other researchers in 2022, where five different samples of cultivated fields of watermelon and canning tomato were collected, concluded that microplastics were found in all the soil samples at different depths. It also stated that microplastic concentration in soils was higher in portions of land closer to suburban roads where fruits are covered with protective plastic coats and are easily shattered by wind and human activities.

The accumulation of microplastics in field soil can cause numerous negative impacts on crop production (Qi et al., 2018). This is due to their physical properties which can alter the soil structure and its properties, affect nutrients transport and availability, modify microbial activities, slow down the development and growth of crops and influence greenhouse gas emissions (Ibarra-Jiménez et al., 2011; Kim et al., 2014; Gong et al., 2015).

Indeed, microplastics in the soil signify an alteration in "plant biomass, tissue elemental composition, root traits and microbial activities" (De Souza Machado et al., 2019). In addition to this, residual plastic debris can modify substrate availability (Fei et al., 2020; Yu et al., 2020; Lozano et al., 2021) and soil pH due to their chemical composition. However, it is worth mentioning that microplastics in soils do not only affect the ecosystem's physical characteristics and soil flora, but also its fauna (Fei et al., 2020; Cheng et al., 2021).

Soil animals (such as earthworms, mites, collembolan and nematodes) are capable of bringing microplastics into the soil by absorbing these pollutants on the soil surface (Leed and Smithson, 2019). For instance, earthworms can ingest these minuscule plastic particles located in the uppermost layer of the ground and generate secondary microplastics inside their bodies, which eventually end up inside the plant's rhizosphere (region of the soil influenced by plant roots) due to their digging movements (Figure 4, Chae and An, 2018). Although, there are no concluding statements on how microplastic degradation in the soil affects the organisms in the plant's rhizosphere (Wang et al., 2019).

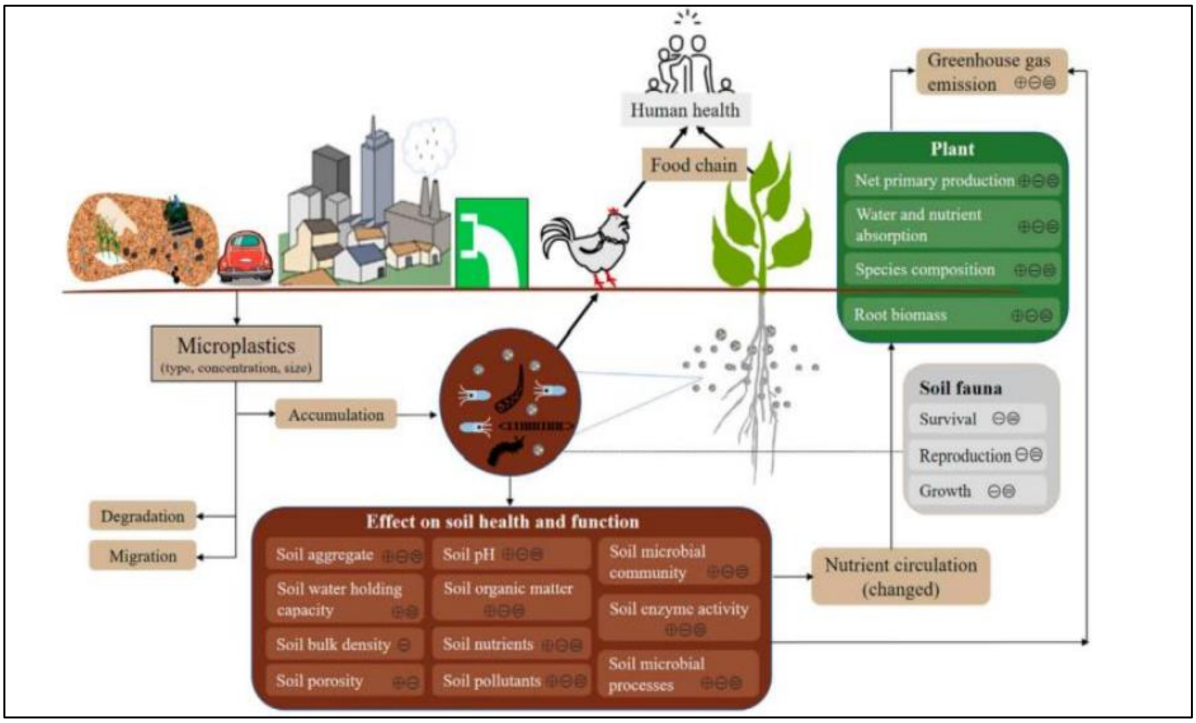

Fig.4. Microplastics in agricultural soils and their impacts on the environment. Source https://www.researchgate.net/profile/B-Pavan-Naik/publication/364311945_Microplastics_in_food_and_agriculture/links/6345e12d9cb4fe44f31d99e0/Microplastics-in-food-and-agriculture.pdf

Overall, it is worth mentioning that all these residual microplastics found in soils will ultimately be transferred into water bodies. This mobility is caused partly by agricultural water runoff, causing water pollution in lakes (Sighicelli et al., 2018), rivers (Anderson et al., 2017), and the sea (Yu et al., 2016; Zhang et al., 2017). Hence, the cycle of microplastics affects and conditions all types of environments.

2.4 HUMAN EXPOSURE TO MICROPLASTICS

Apart from the evident risk that ingestion of microplastics proposes for humans, inhalation and skin contact are other pathways which threaten our health and wellbeing (Dris et al., 2017; Prata et al., 2020).

Small plastic particles suspended in the air (denominated airborne microplastics) come from various sources, but primordially from "synthetic textiles, powdered synthetic rubber tires and city dust" (Prata, 2018). These particles travel long distances carried by wind flows and eventually end up in water bodies, the soil, or directly inhaled by organisms like humans.

Moving on to the relationship between microplastics and the skin, it is necessary to clarify that even though the main function of this organ is to prevent microplastics to pass directly through the tissue structures, possible entry routes include sweat glands, open skin injuries or hair follicles (Schneider et al., 2009).

All sources of exposure are key to evaluate the real impact microplastics pose in humans, yet ingestion of microplastic-contaminated food is however the major route of exposure of microplastics in humans (Toussaint et al., 2019). Even though microplastics in the soil are ingested by soil organisms which contribute to the risk of human exposure from the consumption of these terrestrial organisms, seafood is actually the predominant menace. Marine creatures are increasingly vulnerable to xenobiotics (chemical compounds that are not expected to be present in their biochemistry) and evolving contaminants from the environment (Thompson and Darwish 2019). After sea creatures ingest these microplastic particles present in the water, they are unable to break down the synthetic polymers, meaning that the plastic debris can't be digested and is therefore retained in their digestive systems (Guzzetti et al., 2018). Recent studies have already reported the existence of microplastics in commercial seafood from markets (Cho et al., 2019; Li et al., 2018b), to the point of also detecting microplastics in drinking mineral water (Schymanski et al., 2018). Van Cauwenberghe and Janssen (2014) argued that the European minor shellfish consumers ingest 1800 microplastics annually, whereas top shellfish consumers could ingest up to 11,000 microplastics per year.

Microplastics are transferred throughout the multiple, complex and entangled food webs (Setälä et al., 2014) and start to bioaccumulate in diverse organisms (Figure 5). As a result, contamination of other edible products is inevitable. In fact, seafood and bottled water are not the only products infested by microplastics. Other evidenced goods contaminated with microplastics are beer, tap water (Kosuth et al., 2018), table salts (Renzi and Blašković 2018), food stored in cans (Karami et al., 2018), sugar and honey (Liebezeit and Liebezeit 2013). Accordingly, the global contamination of microplastics is present even in our own dishes at the dinner table, and thus perpetuated by the consumption of numerous food items (Akoueson et al., 2020).

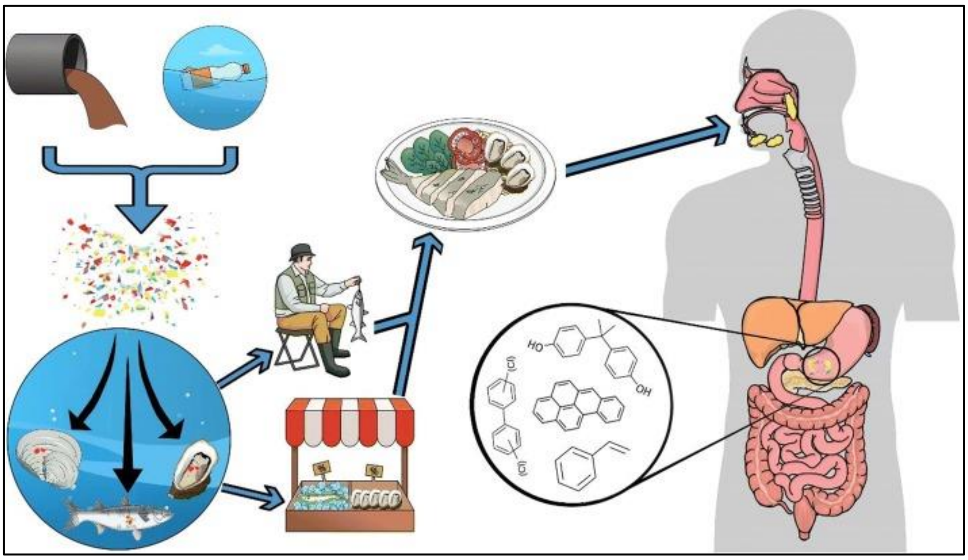

Fig. 5. Drawing showing the different pathways of microplastics entering in our food webs. Source: Microplastic https://www.researchgate.net/profile/B-Pavan Naik/publication/364311945_Microplastics_in_food_and_agriculture/links/6345e12d9cb4fe44f31d99e0/Microplastics-in-food-and-agriculture.pdf s: an emerging threat to food security and human health - PMC (nih.gov)

All these reports emphasize the fact that microplastics have become present in food and drinks, thus, existing in our daily lives. Even if their concentration isn't threatening enough yet, long-term exposure and ingestion of microplastics poses potential risks to human health (De-la-Torre, 2020). In all biological systems, this mentioned exposure to microplastics may cause "particle toxicity, with oxidative stress, inflammatory lesions and increased uptake or translocation" (Che Prata et al., 2019). The immune system is unable to remove the synthetic particles present in microplastics and this leads to an increased risk of inflammation and neoplasia (abnormal growth of cell tissue, linked to tumors). Furthermore, microplastics can release harmful absorbed contaminants and pathogenic organisms into our systems.

Ballesteros (2020) added that the interaction of polystyrene nanoparticles and our bodies resulted in an increase of DNA damages in particular types of white blood cells (specifically, monocytes and polymorphonuclear cells). In addition, it is also reported that nano-sized plastic particles "can access all organs and be transported across cellular membranes" (Bouwmeester et al., 2015).

Overall, it must be considered that the toxicity of microplastics in humans is a new emergent issue and, consequently, we are still learning about their long-term effects on human health. There's a certain scarcity in precise research papers that can enlighten the way towards a full understanding and comprehension of the absolute threats. However, scientific articles still advocate that microplastic toxicity is largely influenced by exposure concentration, quantity of absorbed contaminants and individual sensitivity. Further investigation is now needed to draw final conclusions.

2.5 LEGAL FREMEWORK FOR THE DIDACTIC APPROACH

Due to the growing number of global environmental problems such as microplastic pollution that our societies are facing, there has been an increased interest and awareness, as well as a need to respond to them by encouraging pro-environmental behavior in schools as a pathway towards achieving sustainability goals (Keizer et al., 2016; Truelove et al., 2016; Cheang et al., 2019).

Environmental education and more specifically, plastic pollution in primary schools has frequently been overlooked, and such a circumstance results in a major challenge for environmental awareness (Dalu et al., 2020). However, there’s been numerous schools around the world which are beginning to recognize the importance of diverse environmental issues including microplastics within the walls of their primary education institutions. For instance, Taynuilt and Kilchrenan Primary Schools located in Scotland paired up with Crùbag (an independent organization) and scientists of the Scottish Association for Marine Science (SAMS) in 202 to carry out a project about microplastic pollution awareness to year 6 and 7 students. The project included a tour around research labs to monitor microplastic presence in the local environment, visits around the local Ocean Explorer Centre, beach clean-ups, data-collection, sampling fieldwork, art projects using microplastics and many more interactive activities. In addition, countries like Japan also take microplastic pollution awareness seriously. The Japanese Agency for Marine-Earth Science and Technology (JAMSTEC) have proposed an educational program of microplastic investigation for elementary and middle schools’ students to raise their interest and consciousness about microplastics. Thanks to the continuous and recent scientific research on microplastics, some Regional Governments in Spain (e.g., the Autonomous Community of Catalonia) are also promoting projects in 2023 such as ‘’Schools in Action: microplastics” which receives the support of the Catalan Foundation for Research and Innovation and will carry out various environmental education workshops on microplastics targeted for 5th and 6th grade students in local primary schools.

Regarding Asturias, which is the region where the didactic program is directed towards, students initially learn about plastics in their first year of primary education, distinguishing different types of materials by describing their qualities and characteristics. In this grade they also superficially discuss ways to reduce our plastic consumption (e.g., bringing Tupperware to school instead of wrapping all the snacks in tin foil). Throughout the whole primary education stage, pupils learn about natural resources, waste management and sustainable consumption, following the guidelines of Spanish Ministry of Education and Vocational Training environmental education framework. While microplastics are not specifically mentioned, they could be incorporated into these broader environmental education themes. It is up to individual schools and teachers to decide how to add emergent topics such as microplastics into their programs.

The introduction of microplastics into Asturian primary schools is perfectly intertwined with LOMLOE’s educational intentions. For instance, LOMLOE emphasizes a cross-curricular approach to education and hence, the topic of microplastics, thanks to its interdisciplinary definition, can be taught in a plethora of subjects such as science, ethics, arts and social studies. Furthermore, as earlier mentioned, the new Spanish educational law also promotes environmental education and global citizenship as key components to ensure the academic welfare of students. Learning about microplastics will help raise awareness about their environmental impact and foster at the same time sustainable behaviors within the students. We are tackling a global challenge that needs to be faced and just the simple act of addressing the topic in class will already create a foundation of consciousness about the issue that if stimulated throughout their further education, can result in a generation of peers increasingly active in the fight towards a sustainable society. Lastly, it is also worth mentioning how the LOMLOE stresses the need to develop critical thinking skills amongst the student force. Carrying out activities to learn about microplastics will help students to critically assess (with considerable detail and accuracy, as microplastics are not a basic surface level of the issue) the current situation and impact of these small particles within different ecosystems and reflect on solutions to reduce this influence.

Due to their certain complexity, the didactic program proposed later will target students in the third cycle of primary school education, that is, students between 9-12 years old. Therefore, following the current Asturian curriculum, microplastics would be included in the subject of Social Sciences (natural, social, and cultural environment sciences). Further details about its location within the curriculum will be thoroughly defined in the didactic proposal.

Teaching about microplastics includes a whole integrative approach, which involves linking the topic itself to its respective curricular aspects which discuss environmental education issues, boost teacher training about the matter and promote a community integration so the whole educational community is making an effort to adopt measures which contribute to a sustainable outlook.

2.6 CONCLUSIONS AND SYNTHESIS OF THE RESEARCH FOR ITS FUTURE APPLICATION

In light of the research provided, it is reasonable to state that microplastics have become major class pollutants that are present in oceans, freshwater bodies, soils and even in our own food. Their distribution, identification, toxicity and biodegradation has been thoroughly explained through each identified compartment. Microplastics are a global threat because they bring adverse effects to animals and human beings. Possible solutions to ameliorate the situation include ameliorating prevention measures which target global pollution and mass production systems, developing biodegradable polymers and additives which are not single-use and reduce the consumption of plastic while expanding its reuse (Hale et al., 2020).

The general review of the scientific research provided bases itself in two identified principles: (1) Plastic pollution comes down to microplastic and nanoplastic pollution, as large plastics will eventually break down into these small plastic particles and hence, there's a need to explicitly mention them in schools as they are, essentially, the core of the problem, (2) Even though scientific literature and education has put an emphasis on oceans as the epicenter of microplastics, there needs to be a consideration on other compartments which are key for their distribution and origin, such as land surface and soils.

Although the monitoring and analysis of environmental microplastics is still an emergent field in science and consequently analytical methods and samplings are not as precise or informative as to draw final conclusions, literature researched in this dissertation points out evidenced biotoxicological effects of microplastics as well as their environmental implications in a foreseeable future. We don't need further evidence to justify why the teaching of microplastics is necessary in primary schools.

When crafting a didactic program which tries to teach microplastics to primary school children, it is needed to tackle all areas of effect (that being: oceans, soil, freshwater bodies and human exposure). The methodology must go beyond understanding what microplastics are and carry out activities which exemplify the root of the issue and the consequences of the same. It must use case studies like the Great Pacific Garbage Patch or popular agricultural methods like plastic mulching to make students see their real-world relevance and boost an active learning approach.

3. DIDACTIC PROGRAM

Title: Microplastic Academy			**Temporalization**	May-June	**Sessions**	7
Stage	Third	**Grade**	Year 5 (Could be used in year 6 if the LOMLOE is implemented in the whole Primary education)			
Area		Social Sciences (Ciencias Sociales)				
Interdisciplinary relationship with other areas of the curriculum		Other curricular fields which this didactic program expands across include: 1) English. The program will be carried out in this language; 2) Natural Sciences. We are not just learning about the consequences of human interaction in the environment, but also scientific concepts regarding microplastics' composition and influence on the environment and human welfare; 3) Art. Some activities will involve the creative production of an artistic design; 4) Ethical Values. We will foster sustainable actions and mindsets regarding microplastic consumption; and 5) Physical Education. We will have outings that require stamina and physical exercise.				
Educational Intention		Following the Asturian curriculum guidelines, the subjects of Natural and Social Sciences include all disciplines that study the environment and the human interaction that influences it. These fields try to awaken interest in pupils about the world that surrounds them while, at the same time, initiating them into scientific observation, critical thinking, problem statement and formulation of conclusions. So, in other words, these subjects will build a solid scientific foundation which will help students to understand their impact on the world and promote its protection and conservation. Global challenges of the 21^{st} century like microplastic pollution demand our primary educational institutions to give young generations the necessary tools to comprehend, analyze and evaluate these threats and act accordingly under ethical and sustainable principles. As it has been thoroughly evidenced in the researched literature of this project, microplastics are causing serious problems throughout multiple environmental levels, exposing humans to an overwhelming health threat. This is the reason why students need to be aware that microplastic pollution is a global issue, which they will have to face in the foreseeable future and hence, it is relevant they learn from it. The transformative intention characterized by this didactic unit, mixed with the impartation of a considerably detailed scientific background based on critical thinking and research, perfectly links with the basic				

<table>
<tr><td></td><td colspan="2">knowledge and skills that need to be learnt in the third cycle of primary education in two major points:

➢ The observation, classification, correlation identification and anomalies.
➢ Understanding of microplastic characteristics, influence, and toxicity. Individual and collective actions and approaches to tackle the issue.

The primordial objectives of this didactic program are:

1. Recognize the relationship between plastic production and microplastic pollution.
2. Being able to describe the environmental impact of microplastics on oceans, rivers, soils, and our daily lives.
3. Comprehend microplastic characteristics, (composition and identification) sources and toxicity using scientific concepts.
4. Contribute to the design and carry out of a scientific experiment, formulating our hypothesis and following the scientific method.
5. Understand how and why plastics must be recycled.
6. Learn basic skills to work collaboratively in groups.
7. Investigate and analyze solutions and alternatives to traditional plastics to ameliorate microplastic pollution.
8. Identify everyday products made up of harmful plastic that could eventually degrade into microplastics.</td></tr>
<tr><td>Relationship with ODS 2030</td><td colspan="2">Objetivos de Desarrollo Sostenible (ODS) de la Agenda 2030:

ODS-3 Health and well-being: Education can make the change to foment healthy lifestyles to ensure our well-being.

ODS-9 Industry, innovation and infrastructure: Acquisition of basic competences to be advocates for an increasingly sustainable industrialization.

ODS-12 Responsible production and consumption:
Education must promote the behavior standards that must exist to achieve a sustainable production of goods/services and an ecological consumption of the same.

ODS-14 Marine life: The importance of education in the creation of marine awareness, including active responsibilities in its conservation and sustainable use of its resources.

ODS-15 Life in terrestrial ecosystems: Education must develop skills and capacities to build sustainable livelihoods. They must contribute to the conservation of natural resources and biological diversity, particularly in vulnerable environments threatened and conditioned by human pressures.</td></tr>
<tr><td colspan="3">Link with curricular elements (shown in Spanish)</td></tr>
<tr><td>Competencias específicas</td><td>Criterios de evaluación</td><td>Descriptores del perfil de salida</td></tr>
</table>

1. Identificar las características de los diferentes elementos o sistemas del medio natural, social y cultural, analizando su organización y propiedades, y estableciendo relaciones entre los mismos, para reconocer el valor del patrimonio cultural y natural y emprender acciones para un uso responsable, su conservación y mejora.	1.2. Establecer conexiones sencillas entre diferentes elementos del medio natural social y cultural mostrando comprensión de las relaciones que se establecen. 1.3. Valorar, proteger y mostrar actitudes de conservación y mejora del patrimonio natural y cultural a través de propuestas y acciones que reflejen compromisos y conductas en favor de la sostenibilidad.	STEM1, STEM2, STEM4, STEM5, CD1, CC4, CE1, CCEC1.
2. Identificar las causas y consecuencias de la intervención humana en el entorno, integrando los planos sociales, económico, cultural, tecnológico y ambiental, para favorecer la capacidad para afrontar problemas, buscar soluciones y actuar de manera individual y colaborativa en su resolución, poniendo en práctica hábitos de vida sostenibles y consecuentes con el respeto, cuidado y protección de las personas y del planeta.	2.1. Promover hábitos de vida sostenible y consecuentes con el respeto, los cuidados y la protección de las personas y del planeta, a partir del análisis crítico de la intervención humana en el entorno.	CCL5, STEM2, STEM5, CPSAA4, CC1, CC3, CC4, CE1.
3. Observar, comprender e interpretar continuidades y cambios del medio social y cultural, analizando relaciones de causalidad, simultaneidad y sucesión para explicar y valorar las relaciones entre diferentes elementos y acontecimientos.	3.1. Analizar relaciones de causalidad, simultaneidad y sucesión entre diferentes elementos del medio social y cultural desde la Edad Media hasta la actualidad, situando hechos en ejes cronológicos.	CCL3, STEM4, CPSAA4, CC1, CC3, CE2.
1. Utilizar dispositivos y recursos digitales de forma segura, responsable y eficiente, para buscar información, comunicarse, trabajar de manera individual, en equipo y en red y crear contenido digital de acuerdo a las necesidades digitales del contexto educativo. **(Ciencias de la Naturaleza)**	1.1. Utilizar recursos digitales de acuerdo con las necesidades del contexto educativo de forma segura y eficiente, buscando información, comunicándose y trabajando de forma individual, en equipo y en red y creando contenidos digitales sencillos. (Ciencias de la Naturaleza)	CCL3, STEM4, CD1, CD2, CD3, CD4, CD5.
2. Plantear y dar respuesta a cuestiones científicas sencillas, utilizando diferentes técnicas, instrumentos y modelos propios del pensamiento científico, para interpretar y explicar hechos y fenómenos que ocurren en el medio natural, social y cultural. **(Ciencias de la Naturaleza)**	2.2. Buscar, seleccionar y contrastar información, de diferentes fuentes seguras y fiables, usando los criterios de fiabilidad de fuentes, adquiriendo léxico científico básico, utilizándola en investigaciones relacionadas con el medio natural, social y cultural. **(Ciencias de la Naturaleza)** 2.3. Diseñar y realizar experimentos guiados, cuando la investigación lo requiera, utilizando diferentes técnicas de indagación y modelos,	CCL1, CCL2, CCL3, STEM2, STEM4, CD1, CD2, CC4.

	empleando de forma segura los instrumentos y dispositivos apropiados, realizando observaciones y mediciones precisas y registrándolas correctamente. **(Ciencias de la Naturaleza)** 2.5. Comunicar los resultados de las investigaciones adaptando el mensaje y el formato a la audiencia que va dirigido, utilizando lenguaje científico y explicando los pasos seguidos. **(Ciencias de la Naturaleza)**	
5. Identificar las características de los diferentes elementos o sistemas del medio natural, social y cultural, analizando su organización y propiedades, y estableciendo relaciones entre los mismos, para reconocer el valor del patrimonio cultural y natural, conservarlo, mejorarlo y emprender acciones para su uso responsable. (Ciencias de la Naturaleza)	5.1. Identificar y analizar las características, la organización y las propiedades de los elementos del medio natural, social y cultural a través de la indagación utilizando las herramientas y procesos adecuados.	STEM1, STEM2, STEM4, STEM5, CD1, CC4, CE1, CCEC1.

Mandatory knowledgements (“Saberes Básicos”)

Based in the “Decreto 57/2022 de 5 de agosto, por el que se regula la ordenación y se establece el currículo de la Educación Primaria en el Principado de Asturias.”

A. Cultura científica. (Ciencias Naturales)

1. Iniciación a la actividad científica:

- Vocabulario científico básico relacionado con las diferentes investigaciones.
- Fomento de la curiosidad, la iniciativa, la constancia y el sentido de la responsabilidad en la realización de las diferentes investigaciones.
- Fomento de la curiosidad, la iniciativa, la constancia y el sentido de la responsabilidad en la realización de las diferentes investigaciones.
- La relación entre los avances en matemáticas, ciencia, ingeniería y tecnología para comprender la evolución de la sociedad en el ámbito científico-tecnológico.

B. Tecnología y digitalización. (Ciencias Naturales)

1. Digitalización del entorno personal de aprendizaje:

Dispositivos y recursos digitales de acuerdo con las necesidades del contexto educativo.
- Estrategias de búsquedas de información seguras y eficientes en Internet (valoración, discriminación, selección, organización y propiedad intelectual).

C. Sociedades y territorios

1. Retos del mundo actual:

   El futuro de la Tierra y del universo. Los fenómenos físicos relacionados con la Tierra y el universo y su repercusión en la vida diaria y en el entorno. La exploración espacial y la observación del cielo; la contaminación lumínica

2. Sociedades en el tiempo:

El patrimonio natural y cultural como bien y recurso; su uso, cuidado y conservación.

3. Alfabetización cívica:

La cultura de paz y no violencia. El pensamiento crítico como herramienta para el análisis de los conflictos de intereses. El reconocimiento de las víctimas de la violencia

4. Conciencia ecosocial:

Responsabilidad ecosocial. Ecodependencia, interdependencia e interrelación entre personas, sociedades y medio natural.

El desarrollo sostenible. La actividad humana sobre el espacio y la explotación de los recursos. La actividad económica y la distribución de la riqueza: desigualdad social y regional en el mundo, en España y en el Principado de Asturias. Los Objetivos de Desarrollo Sostenible

Economía verde. La influencia de los mercados (de bienes, financiero y laboral) en la vida de la ciudadanía. Responsabilidad social y ambiental de las empresas. Publicidad, consumo responsable (necesidades y deseos) y derechos del consumidor.

Estilos de vida sostenible: los límites del planeta y el agotamiento de recursos. La huella ecológica.

In the ‘’Sociedades y territorios” section, there is a clear emphasis on present-day challenges and situations of our global environment, with the clear intention of introducing students in real-world scenarios through civic, supportive and committed ways. These basic guidelines offered in the new educational law (LOMLOE) will allow students to develop a personal interpretation of the world while analyzing the relationships between real elements. This will, eventually, make pupils comprehend the evolution of societies over time and space, as well as the change in their environmental impact. Finally, by following these basic knowledges, students will be able to acquire sustainable living habits and develop a sense of care and value towards natural environments in a contextualized way.

Methodology		
☐ Problem-based learning ☐ Project-based learning ☐ Cooperative learning ☐ Design Thinking	☐ Service learning ☐ Visual Thinking ☐ Gamification	☐ Computational thinking ☐ Group dynamics ☐ Class-group explications

This didactic program is a tool for students to face global challenges of the 21st century, and more specifically, microplastic pollution. The main pedagogic methodologies which are enclosed within the didactic approach are:

❖ **Significative learning:** Pupil’s learning resides in their previous background learning. It is essential to place emphasis on what is close and familiar to the pupil’s context yet adding some interactive measures in order to balance supported learning with a boost of interest and participation. Competence-based learning is vital to not only make students acquire knowledge, but also to be able to access and apply it in different contexts of their lives. This means to contextualize it, hence the importance of applying real life examples and scenarios to the activities proposed. We build upon the knowledge of the pupils themselves to extend those ideas to explore the world around them.

❖ **Case studies:** We use examples and settings where the microplastic pollution can be explained. We collect and analyze real data to pinpoint the real issues blossoming from microplastic overproduction. Working with case studies provides descriptive information while also enabling in-depth or even sharpened understanding of the matter.

❖ **CLIL:** Students are learning the subject of Environmental Sciences while they are learning a second language. Thus, they will not only learn science but also gain relevant vocabulary and language skills.

❖ **Use of TIC:** As mentioned, we use digital resources to help us carry out the activities.

❖ **Problem-based learning:** Students are the center of the didactic unit, and we aim to solve an open-ended issue that engages pupils in STEM disciplines. This problem is what drives the motivation and the learning.

❖ **Project-based work:** The didactic unit is an integral learning process which aims to achieve academic competences through the fulfillment of a collective task or project.

❖ **Service-learning:** The outing included in this didactic program offers a service to the community by ameliorating the state of the same. Students will contribute to the welfare of their close environment.

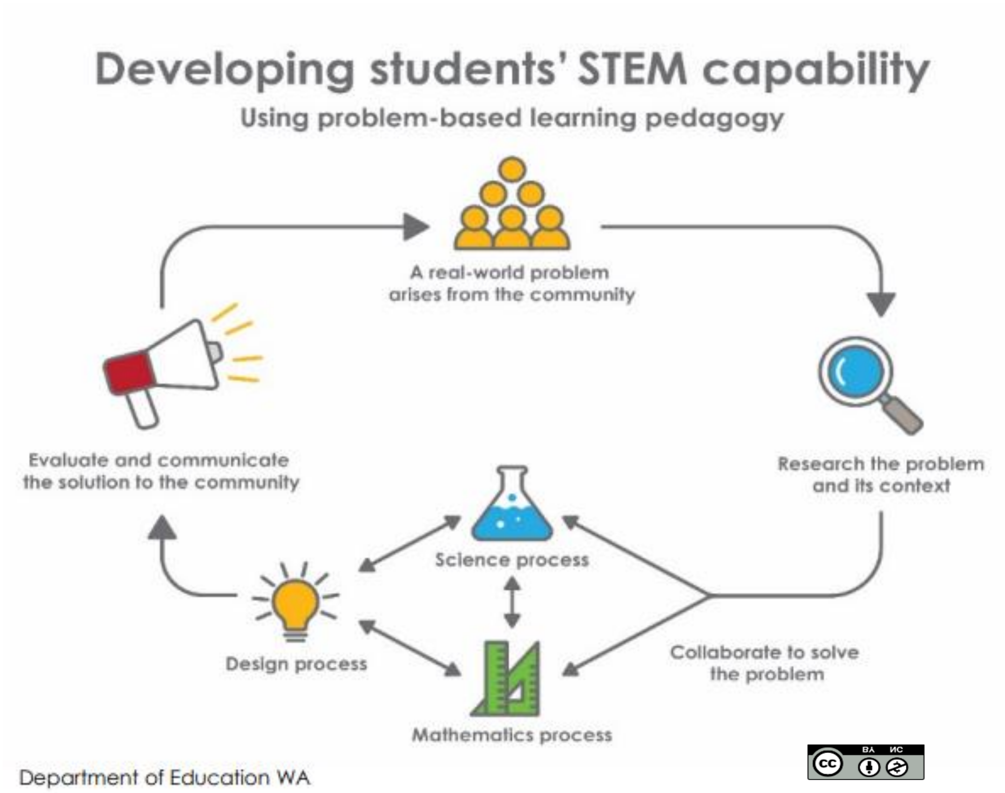

Fig. 6: Developing student's STEM capability. Source: © Department of Education Western Australia 2020: Plastic pollution 1.0

As mentioned earlier, this didactic unit follows the approach of problem-based learning, where students are faced with a real global threat and, through a series of collaborative investigations, experimental research, and design processes, understand the depth of the issue while also being aware of possible solutions which will then, be communicated to the rest of the community.

Groupings	
☐ Heteregeneous groups ☐ Whole class group activities	☐ Flexible teams ☐ Individual work
Apart from individual tasks, students will work in small groups and there are some activities which will involve the whole class group, such as class debates or presentations. Thus, students will have to interact with other peers to fulfill the completion of the whole didactic unit. In case there's students with special educational needs, the proposed activities will be flexible in terms of rules, duration, intensity, rhythm, etc., and their carrying out will be in accordance with the interest and motivation of the students. In this way, individualized learning will be facilitated.	

Didactic sequence	
Resources needed	**Description of the session**
Screen projector Computer Picture stimulus presentation ''I see, I think, I wonder'' worksheet	**Session 1: Introduction** **Starter: Picture stimulus + ''I see, I think, I wonder'' worksheet (Annex I) (20mins)** This first visual activity is crafted merely to introduce students into the topics of plastic and microplastic pollution. We will gather their initial thoughts and opinions about these issues, while also tackling possible questions that they might have. It is crucial to link plastic pollution to microplastic pollution in this introductory activity, as we are building upon existing knowledge which implies further understanding and comprehension. **Introductory video into the matter + Open discussion: (15mins)** (363) The Story of Microplastic - YouThttps://www.youtube.com/watch?v=8MyRiG2ih_Uube This video is recommendable as it explains how microplastics are everywhere and not just in our oceans. It also gives additional visual media which makes the knowledge more memorable and easier to digest. After the video is watched and any misconception/doubt is resolved, a group-class open debate will start by the teacher roaming around these two conversation starters: 1. Why is plastic pollution, essentially, microplastic pollution? 2. If you had to classify microplastics into two different types? **Types of microplastic video: (10mins)** https://www.youtube.com/watch?v=8MyRiG2ih_U

	This video will explain the different types of microplastic and thus, is perfectly linked with the previous class debate. The teacher will talk through it giving brief oral explanations as it does not have any audio. The class will collectively contrast what their types were to the official types set up by scientific researchers. **Useful glossary: (10 mins) (Annex II)** For the last part of the session, students will be handed a Terms Glossary, which will be useful in future sessions to discuss the topic of microplastic pollution. The teacher will go through every term, clearing up any doubt or misconception. If there is free time, students can copy the terms into their notebooks and draw a picture with the meaning for every word.
White paper Projector, screen, and computer Microplastic flowchart worksheets	**Session 2: The Great Pacific Garbage Patch - Case study.** **Initial activity: (10mins)** Firstly, students will be divided into teams (approximately 6 teams of 3-4 students). Each team will have to design a mechanism or device that can effectively collect the greatest number of plastics from water as possible. Factors to be considered in the design of these plastic-collectors will be buoyancy, ease of use, functionality, effectiveness, and types of materials used for their creation. This activity encourages creativity and innovation. The group who can explain with coherency how their mechanism would collect plastics wins the challenge. **Jessy: (10mins)** After this initial activity is done, students will collectively watch the following video: https://www.youtube.com/watch?v=vrPBYS5zzF8 In this video, the ''Ocean Clean-Up" project shows us the real most successful mechanism to remove plastic from the ocean, called the Jessy. The video roams around its structure and creation, including a plethora of images and short clips which showcase its effectiveness. After the video-screening, the class will compare their team designs to the real one seen, creating a contrast between both mechanisms while discussing their similar/dissimilar characteristics. **Exploring the Great Pacific Garbage Patch: (15mins)** Firstly, the group class will collectively watch an introductory video of the Great Pacific Garbage Patch, which uses a plethora of infographics to explain all its characteristics: https://www.youtube.com/watch?v=vrPBYS5zzF8 After the screening, there will be a class debate started by the teacher, who will ask the whole group 4 main questions to roam around:

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1. What is the great Pacific Garbage patch and how did it form?
2. What are the main items of plastic waste that contribute to the formation of the garbage patch?
3. How do you think all these plastic items end up in the ocean? Which channels of distribution do you think exist?
4. Why did the video say that this is a never-ending problem? (Inquire into microplastics)

Microplastic flowchart: (20mins)

After the open discussion is finished, students will have to choose one plastic item (it could be anything, from plastic straws to fishing nets) and create a visual flowchart of the key stages of its life: from where it is first created, processed, and manufactured to where it ends up. The flowchart must include all the distribution elements (rivers, lakes, soils) and it is crucial for it to show how that plastic item will eventually degrade into microplastics and end everywhere around us, including in our own bodies (the last part of the video shown stresses this information).

A template of the flowchart will be given to students that require it. **(Annex III)**

Finisher: Plastic tracker interactive map (5mins)

https://theoceancleanup.com/plastic-tracker/

Finally, we will do a collaborative activity with the whole class group, where, using the projector and the interactive screen, we'll use ''The Ocean-clean-up plastic tracker'' website, where students can write different locations and check the whole journey of the plastic waste generated in those regions and where it ends up. We will try with different locations of interest and check where is most probable for plastic waste to end up in the oceans.

Fig. 7: Plastic tracker interface. Source: Own elaboration

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Biodegradable plastic containers

Play-dough.

Recycled materials

Natural elements such as pinecones or pebbles.

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Session 3: Mini-Cropland creation (50mins)

In this interactive lesson, students will be taught about the current relationship between the terrestrial ecosystem and microplastic pollution.

Students will first do individual research online to search for sustainable alternatives

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Plan worksheet Access to computers/tablets (TIC)	to the traditional agricultural practices that contribute to microplastic pollution (that being, plastic mulching, fertilizers overconsumption, sewage irrigation, etc.) These traditional practices will be described beforehand by the teacher, who will sketch in the whiteboard these practices and give brief explanations about them. Pupils will find that some possible alternatives include using eco-friendly plant pots, bio-degradable mulching (made, for instance, of straw or wood) or fabric grow bags. After the initial research is completed, the class will be divided into small groups of 3-4 members. Each team will have to create a sustainable “mini-garden” or ”mini-cropland”, showcasing at least 3 different green agricultural techniques. This mock-up could be created with materials such as: playdough, recycled materials or natural elements. Before crafting the actual mini-garden, students will have to complete the “Creating our own mini-garden Draft” **(Annex IV)** This activity will not only make students aware of microplastics in the soil, but also conscious about sustainable methods to combat traditional malpractices in mainstream agriculture. In addition, it makes pupils be aware that not only the ocean is in danger of microplastic pollution, but also our terrestrial ecosystems, which are, such as we have seen, key in the transportation and distribution of microplastics.  **Fig.8:** Mini-garden creations from various schools. Source: https://lordderamores.com/whats-happening-in-school/miniature-garden
Different household products, such as toothpaste, facial scrub,	**Session 4: Experiment “Understanding the presence of**

laundry detergents, body wash, etc. Microscope set, including Petri dishes and magnifying glasses. Tap water. Tweezers Safety goggles (used for safety during experiment). Experiment Portfolio.	**microplastics in common household items." (50mins)** **Start-up**: Introductory video: https://www.youtube.com/watch?v=aiEBEGKQp_I The main objective of this activity is to showcase how microplastics are present in our daily environment and thus, human exposure is another risk of microplastic pollution. **Experiment:** The procedure of the experiment is the following: 1. We will briefly recap what we learn about microplastics until this session, swiftly roaming around the ideas of soil and oceanic microplastic pollution. 2. The students will be divided into small groups, each formed by 3-4 members. Each team will have a different household item to experiment with. Instructions will be projected onto the screen and safety measures will be provided, such as the importance of the use of safety goggles and proper handling of the microscopes. 3. Students will have to fill up the petri dish with water as it is the test solution we will use. 4. Each team will then have to add a certain amount of their product into the water dish, creating a mixture by shaking and stirring the compound. These movements will physically disperse any potential microplastics. 5. We will have to wait a few minutes while the mixture properly separates existing microplastics. While students wait for this to happen, they will fill up the ''Experiment Portfolio" **(Annex V)**, following the scientific method. 6. Once the mixture is ready for examination, students will use their microscopes (ideally, 1 per team) or in case of not having any, a magnifying glass. Any visible particles/microplastics will be observed and the group will discuss their findings (e.g., amount of microplastics found, color of the mixture, volume/density of the particles, etc.). They can use tweezers to remove some microplastics and examine them carefully on a clean surface. 7. Once the experiment is finished, each group will report their findings to the rest of the class, comparing which household item was found to have more microplastics in its composition. 8. The class will end with an open debate about possible impacts of this microplastics on our health. As teachers, we can introduce open questions such as: "How can we reduce microplastics in our daily life?", "What are the consequences of this exposure to microplastics on our well-being?", "How can we raise awareness about the issue?"  **Fig.9:** Mixture of toothpaste and water. Experiment outcome. Source: https://www.youtube.com/watch?v=3VPyITnZaHQ We are assuming students know how to use microscopes from previous experiments.

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However, help will be given to those teams that require it regarding microscope use.

For students with special educational needs, visual aids will be constantly provided following clear, simplified instructions for each step. They will also benefit from peer-support and collaboration as they will be working in groups, boosting confidence and familiarity.
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Observation Sheets

Parents' Permit
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Session 5: "Beach Clean-up" Outing with observation sheet (Day out)

In this session, we will go beyond the walls of the school and embrace a "service-learning" approach, signing an educational compromise with the environment that surrounds us.

We will have the opportunity to carry out a beach clean-up. Possible locations for this activity will depend on the school's location. However, in Asturias, beaches known for being contaminated with plastics include: Estaño (Gijón), Salinas (Castrillón) or Rodiles (Villaviciosa).

Students will understand how everything covered in class is real and tangible. Our microplastic knowledge comes to life in this activity.

Throughout the outing, students will have to individually complete the Outing Portfolio (Annex VI) created for pupils to realize the degree of microplastic pollution that threatens our own community's beaches and the importance of taking care of these natural paradises.

Fig.10: Source: https://commons.wikimedia.org/wiki/File:Microplastic-found-key-largo-beach-state-park.jpg


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Fig. 11: Microplastic contamination in Asturian beaches. Source: https://www.cope.es/emisoras/asturias/noticias/estas-son-las-tres-playas-asturias-que-van-limpiar-voluntarios-20200926_912708

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Art supplies (glues, scissors, brushes…)

Plastic items recollected

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Session 6: Microplastic Art (50mins)

Using their previous knowledge from microplastics, students will have to create an art piece with the plastic debris they recollected from the previous clean-up outing and/or plastics brought from home. Examples of items made of plastic that they could bring to school include fragments of fishing rods, plastic fibres, synthetic textiles, bottle lids, plastic straws, plastic bags, plastic wraps (such as bubble wrap), ribbons, containers, glitter, bottle caps, etc. They can manipulate, cut, color, and bend their materials in order to create their art projects. Examples such as the ones below will be shown for further inspiration:

Fig. 12: Microplastic art inspiration. Source: https://www.irishtimes.com/life-and-style/the-big-question-about-microplastics-1.4457413

Fig. 13: Microplastic art inspiration. Source: https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.cecil.edu%2Fnews%2Fexhibit-focuses-on-microplastics-pollution&psig=AOvVaw1CyvtaattTOIPDF_fPDMc_&ust=1685142157880000&source=images&cd=vfe&ved=0CBMQjhxqFwoTCMCGhe_Jkf8CFQAAAAAdAAAAABAw

The main objective is to demonstrate how they can represent the issue in an artistic way, conveying their thoughts and communicating the threat that this problem poses. Students can roam around ideas such as: the future of our soil/marine ecosystems, the suffering of marine/terrestrial wildlife, a snapshot of our current situation, possible invented solutions, etc. Pupils can create sculptures, murals, collages, or prints.

Once the students have finished with their art pieces, they will have the opportunity to share with the class their thoughts, inspiration, and artistic process, alongside the meaning of their outcomes and possible concerns for the future.

This activity can also be linked with School fair activities, depending on the center's

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projects. Students can also present this art work to any local art competitions or environmental awareness contests.

Screen projector

Computers with internet connection

Virtual webs such as Google slides/Canva/Genially or Microsoft programs such as PowerPoint

Session 7: Microplastic awareness flyer (50mins-could take more sessions)

The learning goals of this session are encompassed by the need to implement individual and collective measures to contribute to the welfare of our ecosystems. Consequently, this activity aims to promote a transformative mindset within the students which will contribute to creating active and responsible citizens.

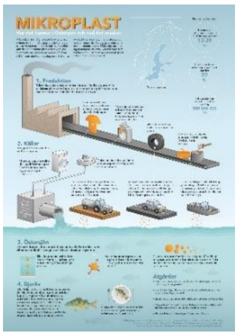
In this session, pupils will work towards the creation of a leaflet using ICT. It will be a group cooperative work (In pairs) using virtual programs such as Canva, alerting the population about the global microplastic pollution crisis.

Students will discuss in pairs the design of the leaflet as well as its content (completing the flyer plan **-Annex VII-**). This content will have to summarize all the information imparted in previous lessons, tackling all areas about the effect of microplastic pollution covered (soil, water, and human exposure). It will also need to have a section that gives examples of laws that politicians and the EU should implement and follow to help the cause.

This lesson will require the fusion of creativity and comprehension. Both elements are key in the successful carrying out of the activity. The product itself serves as a guideline to check if students understood the content of previous lessons and consolidated the knowledge.

After the product is finished, leaflets will be printed out, folded and presented to the class group. Students will also grade their own work using the "Self-reflection student sheet" **(Annex VIII)**

Examples of successful leaflets will be projected onto the board for additional inspiration. These include:



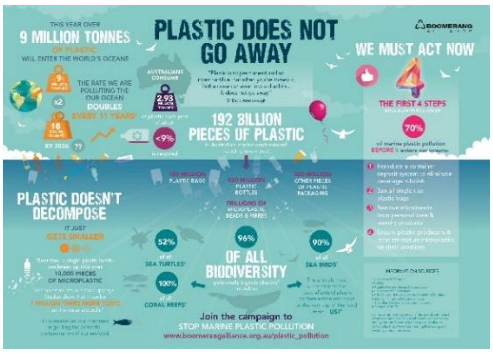


Fig. 14: Inspiration flyers. Sources:
https://www.pinterest.com/pin/tobias-karlsson-microplastic-infographic-swedish--776308054496021927
https://www.landtopia.com.au/resources/microplastic-infographic-final-2016/

Evaluation

Procedures	**Evaluation Activities**	**Instruments**
☐ Direct Observation. ☐ Oral exchanges ☐ Student's productions ☐ Self-evaluation ☐ Peer-evaluation	☐ Class debates ☐ Portfolios ☐ Daily participation and commitment ☐ Class-group presentations	☐ Rubrics ☐ Self-evaluation worksheet ☐ Forms ☐ Evaluation dartboard ☐ Anecdote diary

The evaluation of this didactic program is characterized by being a continuous process (as it encompasses the whole teaching-learning process and is up to date with any obstacles shown or modifications needed) and a global approach (as it is contextualized within the year group's key competences, objectives and has an interdisciplinary approach by learning from multiple areas of the curriculum). The evaluation is crucial to gather evidence about the student's learning while at the same time, ameliorate and upgrade the learning-teaching process and our role as teachers (and therefore, the primordial channel for learning).

Both work performance (task completion, problem solving, understanding and comprehension) and attitude towards work (memory, perseverance, responsibility, respect, teamwork dynamics and concentration) are considered.

The table above defines all the evaluative procedures, as well as evaluated activities and the instruments of evaluation used. It is worth mentioning the importance of self-evaluation, both for the students and the teacher itself, in means of analyzing and criticizing one's own performance to ensure the correct and effective evolution of their teaching-learning process.

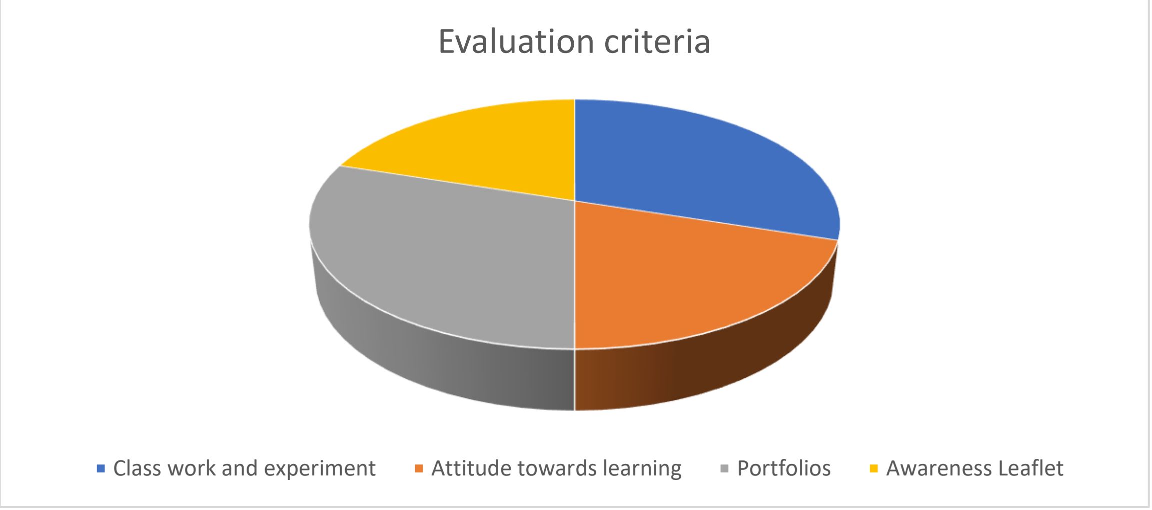


Fig.15: Evaluation criteria. Source: Own elaboration

(Student evaluation rubric and self-evaluation dartboard are shown in **Annex IX and Annex X** respectively**)**

Links with other programs or projects from the school center
A didactic program with the same characteristics than the one proposed could be perfectly connected to school projects such as: 1. Digitalization Plan 2. Attention to Diversity Plan 3. Health and environment Project 4. Bilingual Project 5. eTwinning Project (if applicable)
Complementary activities or extracurricular
The didactic unit proposed includes an outing where a parental permit is needed.

5. CONCLUSIONS

After the scientific research on the literature of microplastics and the creation of a didactic approach that tackles this global issue, we can confirm that this topic can and should be implemented in the Spanish schools.

The didactic proposal embraces modernity by applying interactive activities that are engaging and require the student to reflect on their own learning. Students will grasp knowledge of microplastic pollution looking at it through different lenses and dimensions, submerging into the narrative as if it was a journey of scientific exploration and analytical research. In addition, the objective of adding self-evaluation processes and reflection tasks is for students to build critical thinking, as their voice also matters as they are active participants of their own education and learning. The role of the teacher is purely to guide students through the tasks and give valuable feedback, essentially being an assistant to their learning, as the core of the teaching-learning process resides in the students.

What was also intended in this didactic proposal is to showcase the obligation that teachers have in making the knowledge they impart significative to the students, with the goal to feel motivated, engaged and interested in the matter. Microplastics are not a frozen, abstract, or static concept stranded away from society but rather, a vivid reality which is present everywhere around us and will continue to be in the near future.

On the other hand, the didactic program designed has some limitations. As its own name indicates, the proposal is indeed, just a proposal, and thus lacks the practice needed to test out its effectiveness. Further research could include taking this proposal into a real educational context, transforming the proposal itself into an educational intervention. One must also consider that this educational framework also hugely depends on the school where it will be held, as it involves a plethora of resources, time, parental permits and responsibilities. It would be difficult to perform all the activities with a big student group or with one that had numerous students with different special educational needs, who require multiple modifications of the activities. The tasks designed could prove to be challenging, perhaps not rightfully adjusting to the grade's academic level.

It is also worth mentioning that the topic of microplastics is still an emerging scientific field, and it encompasses a lot of information and key aspects which the proposed didactic program does not include. The topic itself is so immense (and therefore, challenging to adjust in an educational setting) that there's a need to simplify it by perhaps ignoring certain aspects of the same, in means to make it easier to digest and more comprehensible to primary school students.

However, the fact that the topic itself can be defined as demanding to teach is not an excuse for its lack of attention in educational institutions. As Xurxo Torres stated, schools are molded by society, and they can't be considered independently. They are just a reflection of our ideals, morals, and values. While we progressively give increasing importance to sustainability and empathy towards our own environment, we are building the foundations of a society where citizens are active participants that seek a change. This change starts in schools, and the catalyst of this transformation is the impartation of didactic proposals like the one proposed in this project.

In the foreseeable future, more primary education schools will start to implement didactic programs like the one proposed in this bachelor's thesis. This is because we are increasing our concerns about this topic and, consequently, our attention towards it. Nevertheless, imparting didactic programs which tackle the issue of microplastics includes continuous teacher training as they will have to stay up to date with the current scientific findings that are published every year. The primordial action is to adapt this overwhelming information for younger students to comprehend and enjoy learning about it. Essentially, that is where a good educational praxis resides.

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7. ANNEXES

Annex I: (Own elaboration)

Annex II: (Own elaboration)

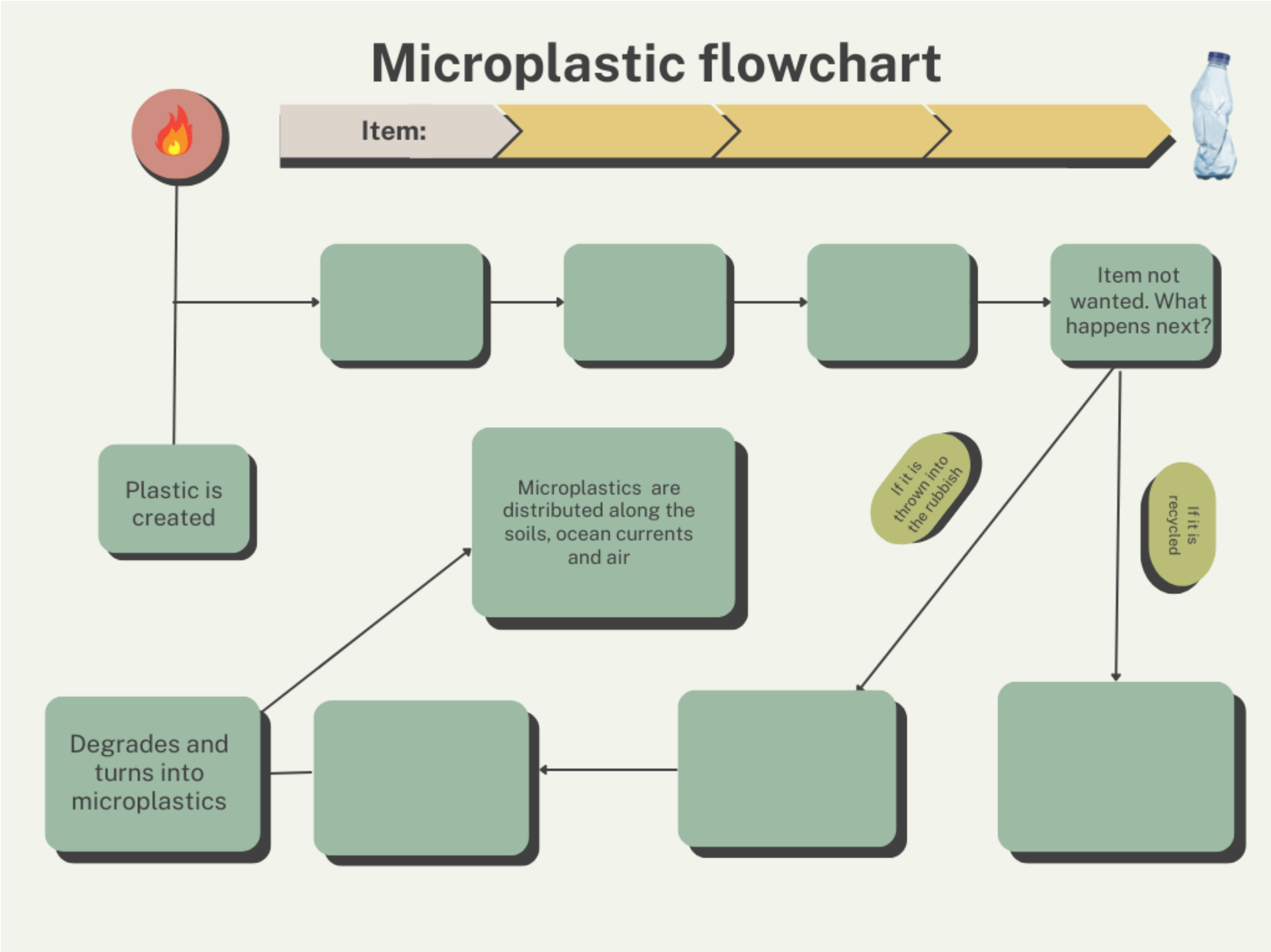
NAME:

PERSONAL GLOSSARY

USEFUL TERMS WE WILL USE IN THIS DIDACTIC UNIT

Word	Dictionary Meaning
Biodegradable	To decay naturally and in a way that is not harmful
Environment	The natural world, especially as affected by human activity.
Ingestion	The process of taking food, drink, or another substance into the body by swallowing or absorbing it.
Microplastic	Really small pieces of plastic debris in the environment resulting from the disposal and breakdown of consumer products and industrial waste.
Microbeads	An extremely small piece of material created for various applications, especially one made of plastic and used in personal care products, cosmetics, and detergents.
Landfill	An area where waste is buried in the ground or piled in large mountains.
Pollution	The presence in or introduction into the environment of a substance which has harmful effects.
Single-use	Designed to be used once and then discarded.
Polymer	A substance with very large molecules – plastics are special kinds of polymers.

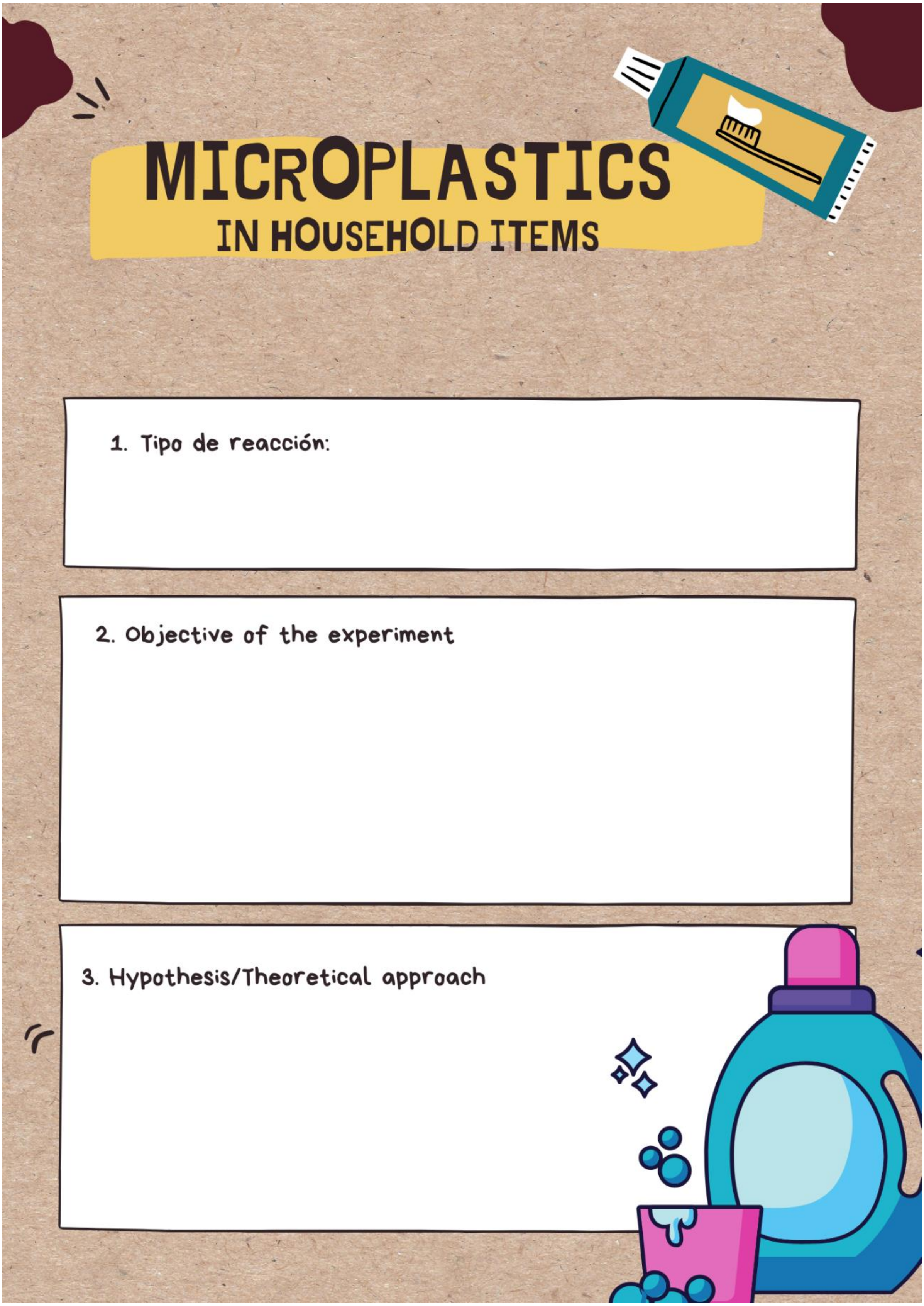
Annex III: (Own elaboration)



Annex IV: (Own elaboration)

1. Skecth your mini-garden (Characteristics, which agricultural methods you will include, measurements…)

Annex V: (Own elaboration)

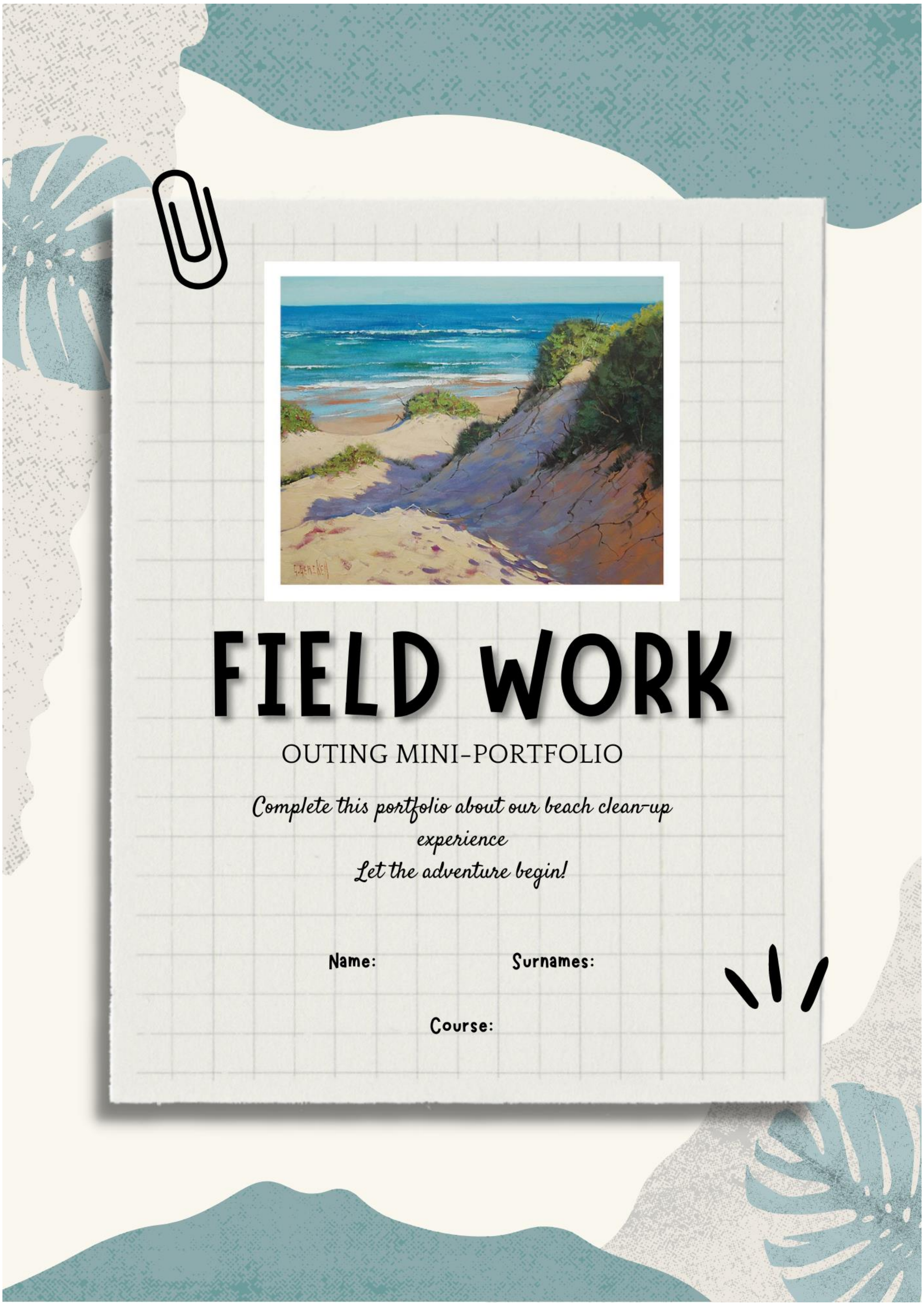

MICROPLASTICS
IN HOUSEHOLD ITEMS
1. Tipo de reacción:
2. Objective of the experiment
3. Hypothesis/Theoretical approach

4. Materials needed

5. Procedure

6. Conclusions

Annex VI: (Own elaboration)



START-UP SHEET

Identifying, locating, describing, classifying, analysing and evaluaitng the landscape.

1. Draw what you can see!

2. Briefly, explain how does participating in this beach clean-up help the marine environment

3. Name 2 wildlife elements AND any human elements that you can observe (if there are any).

PLASTIC ITEMS IDENTIFIED

Draw or describe them!

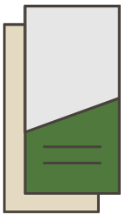
EVALUATE

1. What did you learn about microplastic pollution in the environment?

2. What actions could we take to avoid having plastics in our local beaches?

3. How did this trip make you feel about making a positive change in the environment?

Annex VII: (Own elaboration)



LEAFLET *plan*

GROUP MEMBERS AND ROLES

FOCUS

1 INFO

2 CONSIDERATIONS

TARGET AUDIENCE

IMPORTANT MESSAGE

BACKGROUND INFORMATION

Annex VIII: (Own elaboration)

Name:

Date:

SELF REFLECTION

1. What was your leaflet about?

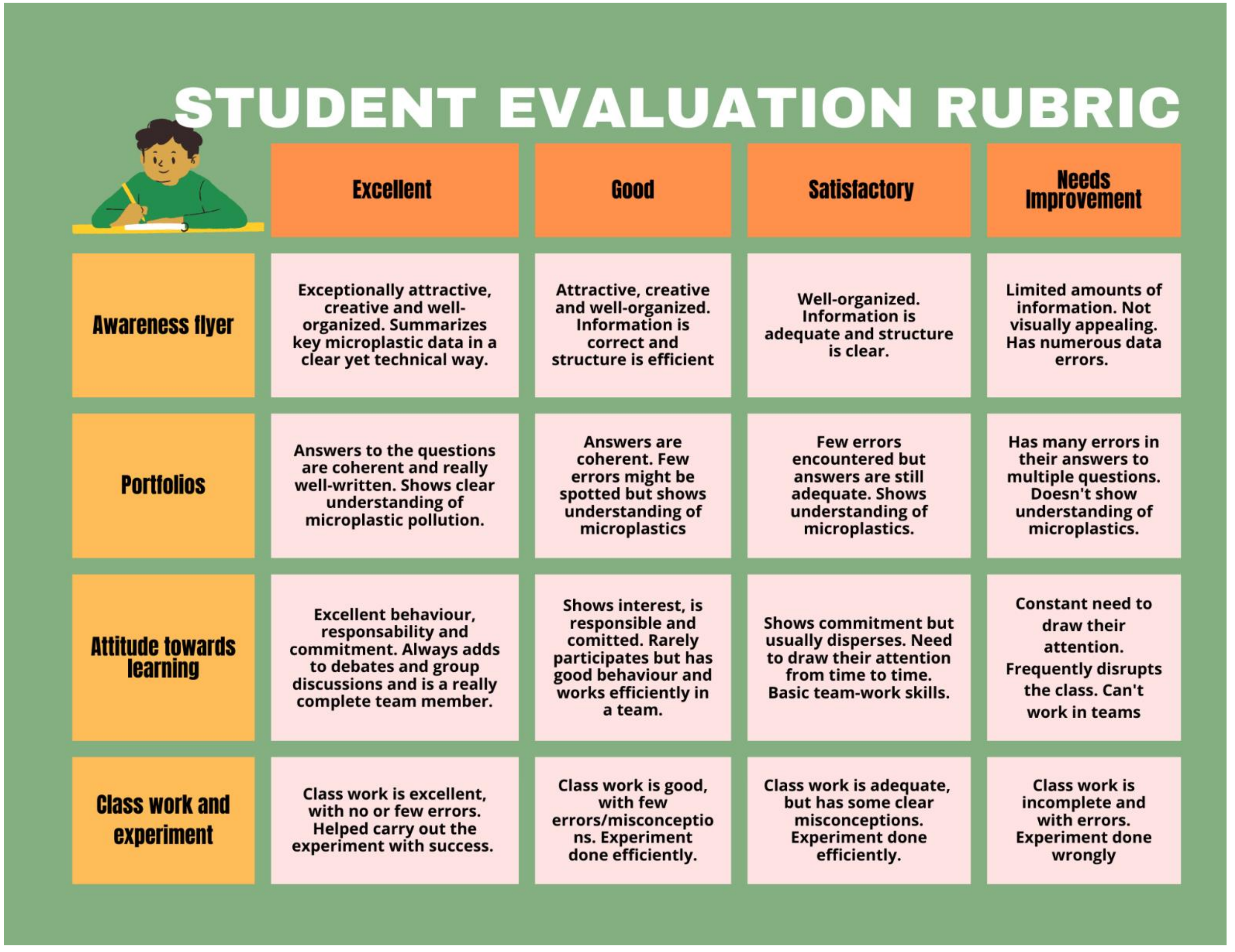
2. What do you like about your leaflet?

3. How did you manage to work in a team?

4. What could you have done better individually?

5. What would you do differently?

Annex IX: (Own elaboration)



STUDENT EVALUATION RUBRIC

	Excellent	Good	Satisfactory	Needs Improvement
Awareness flyer	Exceptionally attractive, creative and well-organized. Summarizes key microplastic data in a clear yet technical way.	Attractive, creative and well-organized. Information is correct and structure is efficient	Well-organized. Information is adequate and structure is clear.	Limited amounts of information. Not visually appealing. Has numerous data errors.
Portfolios	Answers to the questions are coherent and really well-written. Shows clear understanding of microplastic pollution.	Answers are coherent. Few errors might be spotted but shows understanding of microplastics	Few errors encountered but answers are still adequate. Shows understanding of microplastics.	Has many errors in their answers to multiple questions. Doesn't show understanding of microplastics.
Attitude towards learning	Excellent behaviour, responsability and commitment. Always adds to debates and group discussions and is a really complete team member.	Shows interest, is responsible and comitted. Rarely participates but has good behaviour and works efficiently in a team.	Shows commitment but usually disperses. Need to draw their attention from time to time. Basic team-work skills.	Constant need to draw their attention. Frequently disrupts the class. Can't work in teams
Class work and experiment	Class work is excellent, with no or few errors. Helped carry out the experiment with success.	Class work is good, with few errors/misconceptio ns. Experiment done efficiently.	Class work is adequate, but has some clear misconceptions. Experiment done efficiently.	Class work is incomplete and with errors. Experiment done wrongly

Annex X: (Own elaboration)