COVID-19 and the Plastic Crisis: Two Proposals for Environmental Education Approaches

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Abstract. COVID-19 brought a new reality and some problems that already existed intensified. This is the case of the plastic pollution crisis. Lockdowns and fear have led people to buy more disposable materials. In addition, there is another material that contributes to this plastic problem: disposable face masks. These accessories have become essential, but their improper disposal and massive use bring serious threats to ecosystems. Policies are needed, but we all have responsibilities as consumers, and here environmental education is of huge importance to raise people's awareness and give them the knowledge to be critical in this regard.

Keywords. Environmental Education, Face Masks, Plastic Crisis, COVID-19.

1. Introduction

1.1. Historical contextualization

We are in the 21st century, and the technology is in its most advanced stage, and brought enumerable benefits to society, but also new challenges and concerns. Like Richard Rhodes said in his book "Visions Of Technology: A Century Of Vital Debate About Machines Systems A", "technology is the application of science, engineering and industrial organization to create a human-built world" [1]. This field influences all types of communication, political decisions, education, industry, culture, economic, social, and health systems. Basically, it impacts all sectors of our society and, ultimately, human lives [1].

This idea of advance makes us feel empowered to control everything. Some of us think that we are a superior species, and that we can dominate the entire planet, explore all the resources, and make the economy grow faster and unlimitedly to satisfy the human thirst for power [2]. Technology is seen as the support of these expectations. But this idea is probably wrong as we do not have control of the earth system and we cannot explore it infinitely without consequences. Nature ends up contesting, and the appearance of a new pandemic in 2019 seems like another evidence of such.

COVID-19 is a contagious disease caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), and some of the explanations given for the emergence of this pandemic, as well as others, are the degradation of ecosystems and the fragmentation of habitats [3-4]. The human population is growing, overlapping its territory with the one occupied by wildlife, making humans more susceptible to being potential hosts of pathogens carried by wildlife species, which, in turn, might originate new zoonoses. Deforestation with the aim of opening space for crops and building infrastructures, illegal trading of wildlife, intensive domestic animal husbandry, and large-scale distribution of uncontrolled food of animal origin (e.g., wet markets), are all factors that are contributing to the emergence of pandemics like COVID-19 [4], which is being considered as devasting as the world influenza pandemic of 1918 [5]. COVID-19 became detectable in December of 2019 [6], and it was proposed that its origins traced back to a wet market in Wuhan city of Hubei province (China), possibly transmitted from an animal host [4]. However, there are more theories about its origin [6-7].

After the emergence of COVID-19, this Chinese city – one of the most populated in the country - became the epicenter of this human-animal relationship. The limited containment in the beginning, due to the inability of the Chinese authorities to accept the problem and to accurately outline the history and evolution of the first infections and contacts, caused the transmission rate to increase fast [8].

Rapidly, this outbreak spread through China and other countries, enhanced by the Chinese New Year migration [4]. On January 30th, 2020, the World Health Organization (WHO) declared the outbreak as a Chinese International Public Health Emergency [4]. Finally, the Chinese government implemented drastic confinement measures, which resulted in a decrease in the transmission rate. However, it was too late, and the virus had already crossed the borders of

many countries. In the first months of 2020, while in China the situation seemed to be better, in countries like Italy, Iran and South Korea the pandemic situation became very serious [4]. The latency period of about 2 weeks and the asymptomatic host individuals promoted this fast spread [9]. On March 11th, 2020, WHO declared COVID-19 a pandemic [10]. At this date, 118 000 cases of infection had been identified in 114 countries, 4 291 deaths had already been recorded, and the increasing rate of these numbers was notorious [10]. On March 13th, 2020, the WHO considered Europe the active epicenter of the pandemic [11].

Given the severity of this scenario, it was necessary to take measures to address this disease rapidly and effectively. WHO recommended some basic self-protection behavior that becomes essential, like the distance of at least one meter between people, the use of face masks, and the frequent wash of hands (with water and soap or with an alcohol based solution) [12]. Many countries decided to adopt more restrictive measures, including quarantines and curfews, vulgarly known as lockdowns [13]. Many countries in the Schengen Area also restricted free movement by setting up border controls [14]. In April, 2020, nearly 6 billion people worldwide were under some form of lockdown [13]. On June 29th, 2020, WHO warned that, the reopening of some countries' economies, accelerated once again the spread of the virus, in spite of many countries have made progress in slowing down the curve of spread [15]. On July 21st, 2020, the total number of COVID-19 cases worldwide was 14.8 million, with more than 600 000 deaths across six continents [9,16].

Meanwhile, in November, a vaccine from the Pfizer company – proved to have, approximately, 95% of efficacy against serious illness [17] – was approved in Europe [18]. On December 14th, 2020, the emergence of a new coronavirus variant was reported in the South of England, which was named variant of concern 202012/01. This variant was proved as potentially more infectious [19-20]. On January 2nd, 2021, this variant was found in 33 countries around the world. Twenty days later, the total number of COVID-19 infections reported worldwide reached 100 million; by this time more than 2.17 million deaths were registered [21]. In January 2021, almost 77 million vaccines had already been administrated (at least the first dose). Although the vaccine was a great conqueror of science, its contribution to controlling this pandemic needs yet to be assessed. At the time of writing, countries were still dealing with the severe consequences caused by the pandemic, not only in the public health sector but also at a social and an economic level. In fact, millions of jobs were lost due to the lockdowns [22] and, according to the World Bank, up to 100 million people (or even more) could fall into extreme poverty because of it [23].

1.2. Plastic Crisis

1.2.1. Pre-pandemic situation

The term "plastic" refers to a variety of synthetic polymers that, during manufacturing, are "capable of flow such that they can be extruded, moulded, cast, spun or applied as a coating" [24].

In 1907, a material named Bakelite was produced, which later originated the synthetic plastic materials we use today [24-25]. The interest in this new component rapidly increased as its potential was realized: cheap, easy to produce, resistant, malleable, high thermal and electrical insulation properties, and durable [26]. So, in the 1940s and the 1950s, plastics began to be produced on large scales and became more common [24,27]: they were used to package food, medicines, and other goods as well as in construction components and toys [28].

Over time, there was an evolution in this industry and other types of plastic emerged: polyvinylchloride (PVC), polypropylene (PP), polyethylene (PE), polyethylene terephthalate (PET), among others [29]. Some plastics have chemical additives, like bisphenol A (BPA) and polybrominated diphenyl ethers (PBDE), which represent a threat to human health [24]. Today, plastics are a common component of so many products, which is the cause behind their large manufacturing and consumption. This is a problem as many plastics are not recyclable and need hundreds to thousands of years to degrade [27]. In 2017, a study showed that "8.3 billion tons of virgin plastics have been produced to date" of which "4.9 billion tons have ended up in landfills or natural environments" [29-30]. By being deposited in

the environment, they are compromising the ecosystems and posing a serious threat to living organisms [31]. Photographs and videos with marine animals entangled with plastic are somewhat common in media, but unfortunately, there are more effects caused by plastic. Examples include the intake of plastic which may cause a false sensation of satiety, asphyxiation, and other serious health consequences provoked by chemical toxicants in debris, as endocrine disruption, neurological damage, reproductive failure, development issues, muscle damage, immune impairment and cancer [31]. These threats have been reported in species from coastal environments but also in rivers, lakes, soil, and other ecosystems [32-33]. A study estimated the number of floating debris in the oceans to be around 5.25 trillion particles, weighing 268 940 tons [34].

But this environmental problem does not exclusively lay on plastic disposal. Instead, three stages should be considered: production, consumption, and waste management [30]. It is fairly easy to understand how inappropriate waste management may lead to pollution, but the problem does not start here. In fact, if there is no holistic perspective, it will not be possible to address this issue in a sustainable manner [30].

The production (Fig. 1) marks the beginning of the entire plastic cycle. In the United States of America (USA), Middle East and South-East Asia this production is mostly based on fossil fuels [30] whose environmental impacts are well-known [35]. Plus, plastic manufacturing increased drastically. For instance, in 1950, 2 million tons of plastic resins and fibers were produced worldwide [29,36]; in 2015, it was estimated that 380 million tons were manufactured [29]. Plus, only 1% of the 380 million tons of plastics are bio-based and biodegradable, which highlights the need for change [30]. These bio-alternatives face skepticism by costumers, who fear this to be a greenwashing stunt and who raise ethical questions arguing that these products can compete for the same biomass used for food production [30]. Also, they still have problems, as they are not completely biodegradable [37].

The consumption of plastics also plays a critical role in this environmental issue as the awareness and behavior of consumers can either aggravate or ameliorate this problem. In the case of the public, this awareness is more focused on the objects closer to their reality, like bags, bottles, and packaging. In fact, it is necessary for all stakeholders, consumers and industry, developing and developed countries to work together in a holistic way [30]. Of course, policies are essential and the key to solving this, but people have to be responsible too. There is a very important relation between the consumers and the market, and we know that many people simply do not think about it in their daily life, for numerous reasons, included "busy lives" and high prices on environmentally friendly products. Plastic pollution is a reflection of our behavior. It is therefore important to invest in measures that promote public awareness, since this approach has the potential to influence people to adopt environment-friendly attitudes and behavior [40-41].

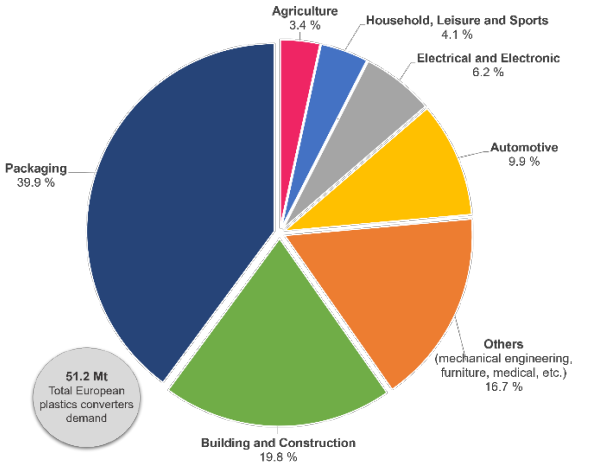

Figure 1. Percentage of plastic used in various economic sectors in Europe, in 2018. Image from [38], adapted from [39]

Regarding waste management, plastics started to be recycled around 1970 [42]. However, nowadays it is known that only a very low percentage of plastic can be recycled. In addition, this issue is amplified by the fact that there is a considerable portion of people in the world that do not recycle [30]. For instance, in the European Union (EU), only 30% of the plastic waste is collected and a large part of this is shipped to third countries [30]. Improving the waste management system is required to improve the overall management of plastics, but this is a complex task. For example, less than 50% of the plastic bottles consumed worldwide are collected for recycling, and only 7% of these are actually recycled into new

bottles [30]. This low percentage of recycled plastic is probably due to the fact that the market does not consider this a profitable alternative to the manufacturing of new plastic [43]. To aggravate this issue furthermore, specially in some developing countries, there is no integration of the informal waste sector, plus there is down-cycling of plastics (e.g., plastic waste is recycled into a less valuable product) [30]. Currently, 79% of the plastic waste ends up in the landfill or in the natural environment, while 9% are recycled and 12% are incinerated [44]. Incineration is another way of dealing with plastic waste, but this option also has a negative impact on the environment, releasing approximately 400 million tons of CO_2 per year, globally [30]. Hence, recycling is really the best choice to deal with plastic waste [45-46]. As we can see below, the use of these two methods has been increasing over time (Fig. 2).

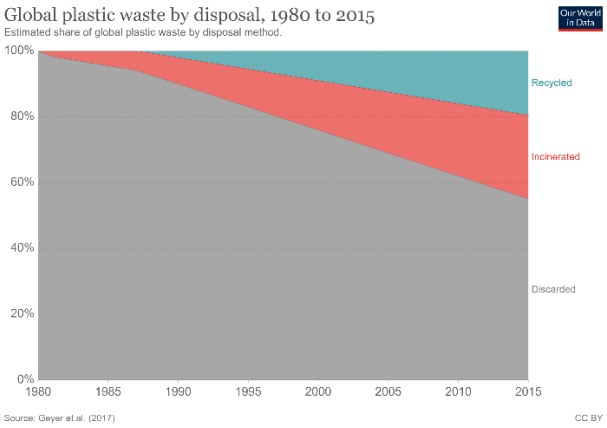

Figure 2. Relative percentage of global plastic waste by disposal method, from 1980 to 2015. Figure by OurWorldInData.org, used under the license CC BY 4.0. Data from [32]

It is estimated that the economic damage of plastic pollution in marine ecosystems is worth at least $13 billion annually (this includes cleaning up beaches and financial losses in tourism and fisheries) [47]. Due to the severity of this issue, several countries launched policies to address it. There are more policies aiming at addressing pollution directly, but as said before, managing plastic waste is not the only important action to take [30]. Much of these policies are focused on groups of objects. For instance, for bags, England, Ireland, Botswana, Portugal, the United States, Buenos Aires and Toronto implemented some public policies [30]. These policies increased from 20, in 2003, to 160, in 2018 [30]. In the case of the microplastics – "any synthetic solid particle or polymeric matrix, with regular or irregular shape and with size ranging from 1 µm to 5 mm, of either primary or secondary manufacturing origin, which are insoluble in water" [48] – there are growing regulations to ban these materials from being incorporated in products [30]. An example of an instrument that is used to deal with this plastic problem is the MARPOL Convention (International Convention for the Prevention of Pollution from Ships), whose annex V has completely banned the disposal of all types of plastics and other garbage by ships in the oceans [27,49]. Regarding recycling, European Member States have been applying a directive to encourage the consumers to recycle and providing measures to prevent the production of packaging waste too [42,50]. In the case of the EU, it was published "A European Strategy for Plastics in a Circular Economy" [51], in order to put into practice pro-environmental policies regarding the plastic issue. A series of objectives was elaborated, within which turns all plastic packaging in EU markets reusable or easily recycled, until 2030 outlining new rules and economic incentives [51]. In 2019 it was launched the Directive 2019/904 by the European Parliament and the Council aimed at reducing the impact on the environment and human health of various plastic products (single-use plastics, products containing oxo-degradable plastics and fishing gears with plastic) and in promoting the circular economy. Reduce consumption, increase restrictions for placing products in the market, define market requirements, place a greater responsibility on producers, separation and collection, and invest in awareness raising measures are the strategies to meet the objectives [52].

Although some advances have been made, they are not enough to sustainably deal with plastics. In an attempt to manifest their discontent, some people created actions like "plastic attack", which consist in a form of protest where people leave the packaging of their products in the supermarket, after buying them. This movement started in the United Kingdom [30] and is one of the examples of how public opinion can force the industry and the market to take action.

1.2.2. During the pandemic situation

In spite of all these positive strategies implemented to achieve the goal of halting the impact of plastics in the environment, the emergence of this pandemic stalled a lot of this advance.

The plastic had and still has at the time of writing, a huge importance to protect humans against COVID-19. Personal Protective Equipment (PPE) had an important role to avoid the propagation of the virus. Among these materials are face masks, latex gloves, shoe covers, face shields, and others [53]. Plus, the public started to realize that plastic materials are more hygienic than others, which, along with the convenience factor, led to an increase in the use of disposable plastics [54]. On another hand, online delivery became more frequent, contributing to the increase of plastic waste (e.g., food and other goods packaging, plastic bags) [55]. However, the massive use and the inadequacies in waste management, as described above, could lead to improper disposal becoming plastic wastes a threat to the environment and to public health [57].

Companies, mainly the ones involved in the plastic industry, saw this pandemic as an opportunity to produce and sell more plastic [55] since some governments also promoted this by rolling back some plastic ban regulations [56]. For instance, Starbucks, that has banned reusable cups temporarily [57], and Illinois grocery stores that banned the use of reusable bags [56]. In addition, the plastic industry, also used this period to influence public's opinion, and for example, the Canadian Plastics Industry Association (CPIA) claimed that single-use plastic bags and other plastic packaging are more hygienic and require fewer resources during production than reusable alternatives [56].

Some national government regulations about measures to address the plastic issue also suffered delays. For instance, in Portugal, the reduction of disposable plastics in the restaurant sector was supposed to start in 2020, but, because of pandemic, this was delayed [58, 59]. In Massachusetts, there was the reintroduction of plastic bags for some retailers [56]. Other states of the USA have rescinded or delayed plastic bag bans too [56]. Similar measures were seen in Hawaii, Canada, South Australia, Italy, Scotland, and United Kingdom [56].

So, the pandemic led to a general increase in plastic waste and medical waste, not only due to enhanced consumption but also because collection, separation and recycling centers and waste treatment facilities were not so active [53, 56]. It is estimated that, globally, around three billion face masks are disposed of every day and that 1.6 million tons of plastic waste are produced daily since the start of the pandemic [53]. Besides, the decrease of employees in this area and capacity constraints due to the pandemic led to inadequate treatment of waste that ends up polluting the environment [55]. During the pandemic, incineration seemed like a practical solution, however reducing, reusing and recycling continued to be the recommended approach, and the incineration structure could not complement the huge rise of plastic generation [55]. Another factor that contributed to the increase of plastic production, was the decrease of the oil price caused by the pandemic constraints, which led to the decrease of the value of virgin plastic in comparison to the recycled ones [55].

We are seeing plastic with the wrong eyes, considering its use as a plethora [53]. But it seems that we are going somewhere now. Fortunately, at the time of writing, there was an advance regarding plastic policy. In Portugal, the government is starting to pay the due attention to this big issue, alongside other European countries. The enforcement of the Directive 2019/904 and of the Portuguese Law 76/2019, September 2nd is finally taking place [52]. According to "decree-law nº. 22-A/2021, March 17th" [59] the restaurants, caterings and drink places have until July 1st, 2021, to adapt and to apply these regulations [58], in particular in what regards single-use plastics. These updates enter into force in Europe on July 3rd [60]. Also, the bags from any material are not anymore free in stores, and in the takeaway services the consumers can use their containers [61]. New Zealand is another country that launched a ban on plastic plates, bowls, straws, fruit labels, bags, cotton buds, and other single-use plastics [62]. In this follow-up, some countries already started in this way before the pandemic [63].

Although there was some advance in plastic policies before and after the pandemic appeared, little was done regarding specifically the issue of disposable face masks. The incorrect disposal of these items in streets, gardens, beaches, and other public places is notorious [64]. In fact, the World Wide Fund of Nature (WWF) published that "if just 1% of the masks were disposed of incorrectly and dispersed in nature, this would result in as many as 10 million masks per month polluting the environment" [65]. If one mask has approximately four grams, this would mean that, per month, 40 000 kg of plastic would be deposited in nature [65]. It is a serious problem that is getting bigger right in front of us [65].

The pandemic can be seen as an opportunity for humans to learn and respect the environment. A time to take advantage of the effects of quarantine periods – like the decrease in the carbon footprint, the improved air, and water quality – and revert the tendency of plastic pollution [53]. Some world economies are working towards this goal. For example, the European Union committed to devoting 25% of its economic stimulus for the pandemic crises to climate-friendly measures [55]. Meanwhile, South Korea committed to reduce greenhouse gas emissions to net-zero values by 2050 [55]. But, once again, regarding the disposable face masks not much has been done.

2. Environmental Education Strategies

Today, it is widely acknowledged that public engagement plays a vital role in Nature conservation [66-68]. For instance, people that are interested and informed about conservation can demand better conservation practices from the government [66, 68]. Besides, in order to address the underlying causes leading to biodiversity loss (including pollution), society must change its behavior [66-67]. Increasing public knowledge constitutes a way to foster willingness to that change and adopt ecological behavior [40,66-67].

Environmental Education has three main lines of action: (1) transmit information about the environment to citizens, (2) provide tools to help them improve and change their habits, and (3) encourage critical thinking so they are able of taking their own conclusions and identify problems [69].

Given this context, environmental education seems well-positioned to help to address the current plastic crisis. Hence, in order to increase the awareness of citizens about the problematic of disposable face masks, two environmental education activities were prepared and are being proposed.

2.1. Face mask Degradation Experiment

This hands-on, inquiry-based activity was developed for an audience of secondary school students, who, ideally, would implement it during classes.

The main goal of this experiment is to raise awareness among the students about the plastic crisis in general and also to inform them about the issue of disposable face masks. It is expected that, by having a hands-on experience that demonstrates the low degradability rate of face masks once deposited in the environment, the students will become more aware of this issue and, ultimately, critically think about their face mask choices. By carrying out this experiment, students will be able to answer the following questions:

- Is it possible to detect signs of biodegradation in disposable face masks in the environment?
- Are the two types of disposable face masks identical in regards to their biodegradability?

For the experiment, the students will need:

- 12 surgical masks
- 12 respiratory masks (like KN95)
- Shovels
- 1 camera
- Electronic magnifier
- Incubator
- Weighing scale
- Monitoring notebook
- 1 vase or garden
- Rocks (or small signboards)

In order to execute the experiment, students should follow the steps described below:

1. Organize the face masks in groups as indicated: Control Group S: 3 surgical face masks; Control Group R: 3 respiratory face masks; Group 3-S: 3

surgical face masks; Group 3-R: 3 respiratory face masks; Group 6-S: 3 surgical face masks; Group 6-R: 3 respiratory face masks; Group 9-S: 3 surgical face masks and Group 9-R: 3 respiratory face masks. These numbers (except for the control groups) translate into the number of months that face masks will be buried in the soil.

2. Photograph, weigh, and observe with an electronic magnifying glass the face masks belonging to all the groups. The students must then write in their monitoring notebook the measurements and other data that they think are important (e.g., drawings of what they see, comments about the face mask texture, color, etc.)
3. The next step is to bury them. Students should dig three holes (one for each dig up period), with a depth of approximately 15 - 20 cm. In one hole, the face masks assigned to groups 3-R and 3-S should be buried. Then, the hole should be covered and a rock numbered “3” should be placed on its top, above the soil. In the second hole, all face masks assigned to groups 6-R and 6-S should be buried. Like before, the hole should be covered and a rock placed on top of it, but this rock should be painted with the number 6. All the remaining face masks should be buried in the last hole, which must then be covered. On top of this last hole, a rock numbered “9” should be placed. The numbering in the rocks is intended to make it easier to identify the location of face masks as well as to provide a reminder of when they have to be collected.
4. After 3 months, the face masks buried in hole number 3 should be carefully dug up (example in figure 3).
5. Photograph the unburied face masks, observe them under an electronic magnifier glass, and write down all the relevant information.
6. Carefully clean the face masks and place them on an incubator regulated at 100º C (if this temperature is not possible, use at least 60°C) for at least 12 hours, in order to remove the humidity. Afterwards, the face masks should be removed and weighted.
7. The steps 4 to 6 must be repeated for all the groups once reached the respective unburying date.
8. After unburying and analyzing all face masks, students should analyze all collected data to answer the previously formulated questions.

Figure 3. Masks after being dug up from the ground

To finalize this experiment, the teacher mediating it should promote a discussion about the obtained results as well as about the advantages and disadvantages of each type of face mask available in the market including the reusable ones.

2.2. Itinerant exhibition – “Disposable masks: The Problem of the Solution”

The second proposal is to design an itinerant exhibition and opening it to the general public.

The goals of this exhibition consist in

- Raising awareness among the public about disposable face mask pollution and their correct ways of disposal.
- Capacitating citizens to critically think about which is the most appropriate face mask choice for them.

The concept of the exhibition is divided into four modules. Below, it is described the different ideas behind each of them.

MODULE 1 – The Problem with the Solution

This first introductory module, which will welcome visitants to the exhibition, will entail two large format prints:

- One portraying a compilation of several pictures of face masks in the environment.
- Another entitled "The anatomy of a facemask", which schematically presents the different types of face masks and their composition. This will include microscopy images showing the small fibers that compose face masks.

MODULE 2 – The Biodegradability of Face masks

This module will consist of large format prints that showcase, through a photography storyboard, the methods and results obtained by carrying out the biodegradability experiment described in section 2.1. This will include colored photographs taken with a digital camera as well as artistic, black and white photographs created using a pinhole camera.

MODULE 3 – Which is the Best Face mask Choice?

This module will include a hands-on activity called “Masks in cubes”. In this activity, there are four acrylic cubes; each one has a different type of face mask inside, including surgical face masks, respiratory face masks, homemade cloth face masks and certified cloth face masks. On one side of each cube, it will also be displayed some information, in an infographic format, regarding each face masks’ degree of protection, price, and sustainability. Here, visitants will be challenged to order the cubes from the worst face mask choice to the best, considering all the criteria they find relevant.

Near the end of this module, short messages will be displayed concerning the broad theme “The environment is also in your hands”, to highlight and promote critical thinking about the importance of citizens' behavior towards this problem.

MODULE 4 - BioImages: Sustainable Design and Photography Practices

In this module, it will be explained how the pinhole photographs shown in module 2 were created. For that purpose, several elements are included:

- Hands-on activity called “Guess the Smell”: several opaque containers will be displayed to visitors, with each one holding a different compound used in the making of bio-photographic developers (e.g., coffee, spearmint, and thyme). The challenge here will be for the public to identify the compound using their sense of smell.
- Large format print that illustrates, step by step, the process of preparing the caffenol developer.
- Large format print that uses storytelling to introduce the historical context of the appearance of these bio developers, by presenting Dr. Scott Williams and the Technical Photographic Chemistry 1995 Class [70].
- Large format print about the educational project named “Bioimages”, which has a focus on eco-friendly art practices. Moreover, its goal is to develop sustainable design and photography practices by using biomaterials and recycling methods.
- Showcasing of eco-objects used in the Bioimages project, where people will be able to interact with and be inspired by their eco-design philosophy. These eco-objects will be displayed side by side with their regular versions (e.g., common mortar *VS* eco mortar).

3. Conclusion

The pandemic highlighted our imbalance with the environment. In our political agenda, the environment has to be prioritized as in our daily lives. In the case of plastic, we must take responsibility and be conscious consumers. In this regard, Environment Education is very important to bring these environmental issues to people, in order to make them capable of being critical and confident about their choices, taking into account the environment too. This is what we aim to achieve with these two proposals.

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