# Raising High School Students' Awareness about the Plastics and Bioplastics Topic through Hands-on Activities and Systems Thinking

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## Abstract

*Plastic is a key material, largely used in our everyday life. It is cheap and has modular mechanical and thermal properties, but it often ends up in dumps or in the oceans, polluting the marine ecosystem. Nowadays bioplastics – plastics that are biobased, biodegradable, or both – can offer a valid alternative to traditional plastics: they have the same properties and, in many cases, even provide additional advantages. Schools can play a central role in raising awareness about plastic pollution, the possible alternatives to traditional plastics and the importance of protecting the environment.*
*In this work, we present a pilot learning path, designed for high schools, to approach this complex topic. It was developed in the framework of two European projects: "Raw Matters Ambassadors at Schools" (RM@Schools), an innovative program to make science education attractive for youngsters, and "BIOBec-Preparing the creation of Bio-Based Education Centers", aimed at building bridges between the bio-based innovation processes and the educational system and showing a wider vision on and the opportunities offered by the bioeconomy.*
*The pathway was successfully tested in Bologna (Italy) with 32 high school students, who were involved in a review of the plastics and bioplastics topic through systems thinking and engaged in laboratory experiences to trigger curiosity. The path has a modular structure: (1) Lessons – introducing the students to the relevant knowledge; (2) Activities – hands-on chemical experiments; (3) Communication – students are asked to create products designed to disseminate the key messages they learnt among society. Three hands-on experiments were performed by students, two focused on the chemical-physical properties of different plastics and one on bioplastics. As regards the lessons, they gave an overview of the different chemical structures of plastics and bioplastics, the recycling process and biodegradability, pros and cons of these materials.*
*The third step, Communication, was a key part of the educational path: students were encouraged to communicate the challenges offered by this topic with peers and society; thus they developed surveys and videos for a social media campaign. Finally, the learning assessment showed that this kind of methodological approach raises both the interest of students in the selected topic and their knowledge.*

**Keywords:** plastics, bioplastics, high school, learning-by-doing, systems thinking

## 1. Introduction

In 1997, in their most famous single "Barbie Girl", the Danish group Aqua sang: "Life in plastic, it's fantastic". Even if they were referring to the dolls, they were somehow prophetic: we live in a plastic world, we are surrounded by plastic objects and we can't live without them.
Plastic is a relatively new material (first used about a hundred years ago), nonetheless, it has now a central role in our everyday life. Its wide use is due to many factors: cheapness, resistance to corrosion and hits, lightness, and modular mechanical and thermal qualities. However, plastics have some drawbacks and raises environmental concerns. Plastic objects are often single-use, which creates a high volume of waste every year; plastics non-biodegradability is leading to the ever-growing accumulation of plastics in our oceans and natural environment. Our society has to deal with these problems. The topic is quite complex and has to be studied accordingly: there is no simple solution, but a multi-faceted approach, such as recycling and reuse, consumptions reduction, and bioplastics [1].
The latter can be bio-based, which means (partially) derived from plants, but with the same properties of fossil-based plastics, or biodegradable, which means that microorganisms convert the material into natural substances, or both (Fig. 1). Therefore, they are a promising alternative to conventional plastics,

as they can help to reduce either the plastics persistence in the environment (if biodegradable) or oil dependency, promoting renewable sources (if biobased).

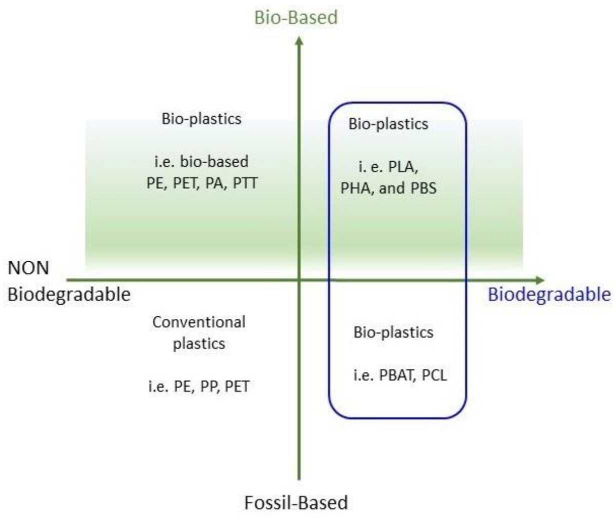


**Figure 1**: Classification of bioplastics taken from *Bioplastics Europe* [2].

Circular Economy and Bio-economy are models to rethink the systems of production-consumption to create a waste-free future, a paradigm shift towards a new industrial policy aimed at sustainability and innovation. Schools can play a central role in raising awareness about plastic pollution, possible solutions and the importance of protecting the environment. It is crucial to invest in students' education to achieve a sustainable society, which can give them a good quality of life preserving at the same time the needs of future generations.

To trigger the students' interest, a learning path for high schools was developed in the framework of *Raw Matters Ambassadors at Schools* (RM@Schools), an European project funded by the European Institute for Innovation and Technology (EIT), [3-6] and *BIOBec - Preparing the creation of Bio-Based Education Centres*, aimed to link some concepts of circular bioeconomy with the ministerial programs of chemistry, biology and technology [7].

## 2. Learning path

### 2.1 Objectives & Path overview

The students were involved in a review of the plastics and bioplastics topic through hands-on activities and systems thinking. The main goal was to increase their sensibility and interest in it, as well as to show that the bio-industry sector needs scientific knowledge, critical thinking and creativity. Other goals were to analyze the complexity of this issue to avoid over-simplification, common beliefs and green-washing slogans, and increase their knowledge of the topic.

The learning path lasted three months and had a modular structure, as shown in Fig. 2.

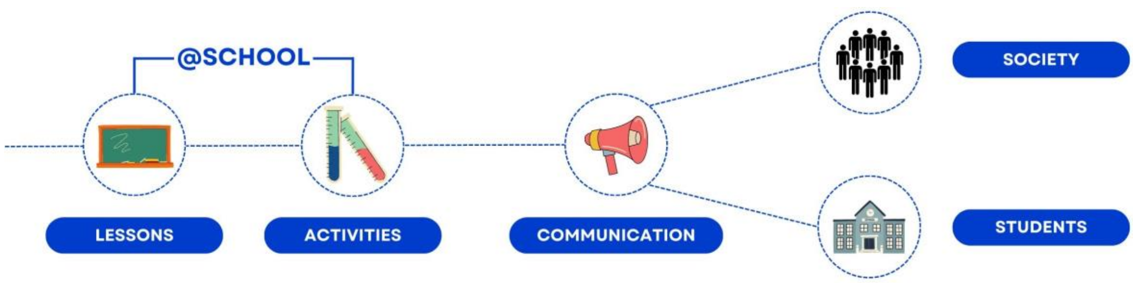


**Figure 2**: The main steps of the RM@Schools learning pathway

**Theorical Lessons** were the first step aimed to introduce students to some key concepts: polymers and plastics, the correlation between chemical structure and properties, comparison between different

plastics and bioplastics, recycling processes, biodegradability, and pros and cons of these materials. In fact, plastics are difficult to recycle because they are made up of a large group of different polymers.
Among all, the definition and characteristics of bioplastics were mostly underlined and emphasized, as the preliminary survey showed many misconceptions about it, i.e. plastics' biodegradability. The lessons also included videos, infographics and schemes to meet different learning styles, and some engaging activities, such as surveys and word clouds.
The second step was hands-on **Activities** to involve the students in chemical experiments (details are given in section 2.2) and link the official curricula with the real challenge we have to face.
The third step was **Communication**: students were asked to design and create dissemination products to transfer what they learned to peers (other high school students) and non-expert people. It is a very important step as students turn into active co-creators of knowledge. They developed surveys, presentations, edu-games, etc (Fig. 3).

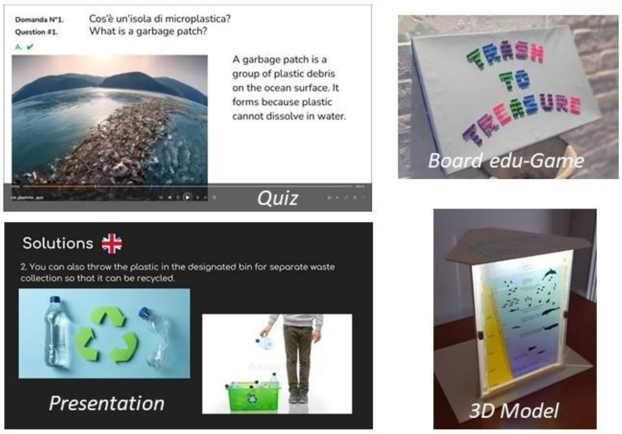


**Figure 3**: Examples of dissemination products realized by high school students.

## 2.2 Activities toolkits

Three different experiments were tested and implemented in this pilot path, two focused on the chemical-physical properties of different plastics, and one on the bioplastics'creation (**Table 1**).

**Table 1.** Hands-on chemical experiments on plastics and bioplastics.

| Toolkit | Target | Learning objectives | Content | Subject links |
|---|---|---|---|---|
| *Sorting plastics* | 11-18 yo | Plastics are made up of a large group of polymers | Plastics separation through densitometry in ethanol-water solutions | Chemistry, Physics, Materials science |
| *Iodine Run* | 15-18 yo | Different plastics have different properties (i.e. permeability to gases) | Demonstration of LDPE[a] permeability to gases through iodine gas production | Chemistry, Physics, Technology, Polymer science |
| *From expired milk to bioplastics* | 11-18 yo | Students gain a deep understanding of the concept of biobased bioplastics and circular economy strategies | Synthesis of a bio-based and biodegradable bioplastic from skimmed milk and vinegar | Chemistry, Biology, Environmental issues, Active Citizenship |

[a]Low-density Polyethylene

### 2.2.1. Sorting plastics

The first experiment involves students in the physical separation of different plastics [8]. To simplify the procedure, just four plastics with different densities have been considered: Polystyrene (PS), Polypropylene (PP), High-density Polyethylene (HDPE), and Polyethylene terephthalate (PET). They were sorted through densitometry. More in detail, different ethanol-water mixtures were used for this experiment: starting from ethanol and adding different amounts of water to change the solution density, floating plastic fragments were progressively separated, as indicated in **Table 2**. The main objectives of this activity were to present different types of plastics and their different properties, and to give a brief overview of the various applications of these four plastics in our everyday life.

**Table 2**. Sorting plastics

| Solution | Sorted plastic |
|---|---|
| Pure ethanol | PS (floating) |
| 10:7 ethanol-water | PP (floating) |
| 5:6 ethanol-water | HDPE (floating) & PET (at the bottom) |

#### 2.2.2. Iodine Run

The second experiment shows how the different uses of plastics are correlated to their chemical structures; for example, not all plastics can be used to make sparkling drinks bottles because it depends on the plastics permeability to gases. In detail, iodine gas ($I_2$) was produced inside a glove made of Low-density Polyethylene (LDPE) through the reaction between copper sulphate ($CuSO_4$) and potassium iodide (KI), which requires about fifteen minutes to occur. To make the gas passage easily visible to the naked eye, the closed glove was soaked in a starch solution, which acquires a purple color in the presence of iodine. Thus, the final conclusion is that LDPE cannot be used to make sparkling drinks bottles as it is $CO_2$-permeable; PET is used instead, despite its higher cost, because it isn't permeable to gas.

#### 2.2.3. From expired milk to bioplastics

The third experiment is a virtuous example of a circular economy process: expired or skimmed milk can be used to create a bioplastic [9]. Milk caseins can coagulate and cross-link in a polymeric structure after adding an acid (i.e. vinegar or lemon juice). The material obtained after 24h-drying is both biodegradable and bio-based. The main objective was to create a valuable product from food waste, a sustainable alternative to fossil-based plastics.

## 3. Results

32 students (16-18 years old) from two different high schools in Bologna (Italy) were involved in this pilot learning path. To assess the effectiveness of the path and to determine whether the students interest towards the topic raised , two surveys were conducted. The first one took place before the beginning of the path, to find out preliminary knowledge, beliefs and misconceptions, and the second one at the end, to assess acquired knowledge and skills.

The results of the final survey showed that the main goals of the learning path were accomplished. As shown in Fig. 4a, the interest and curiosity about the issue significantly increased: 56% answered “much” or “very much”, versus only 25% before the path. The students seemed willing to further investigate this complex topic, especially concerning the recycling process and the impact of plastic pollution on marine ecosystem.

Secondly, their knowledge on the topic increased as well: most of them correctly identified “plastics” as “artificial polymers”, “largely used in our lives due to their many applications” and that different types of plastics can be sorted on the basis of properties such as density, and looking at the codes found on plastic packaging. They also learnt that bioplastics aren't always biodegradable (Fig. 4b).

Last but not least, the experiments (step two of the path) were really appreciated: 75% of the students answered they helped “much” or “very much” in the learning process.

## 4. Conclusions

Raising awareness about plastics and bioplastics, their advantages and problems is very important in our society. It is even more important for youngsters who will become responsible and active citizens. The complexity of the topic is not approached analytically, splitting the problem into smaller parts, but globally, through systems thinking [10]. This approach helps to develop critical thinking, making connections, understanding cause-effect relationships, and considering all the parts in a more general view.

In conclusion, this learning path can help students to get closer to the plastics topic, trying to find possible solutions; it also offers teachers links with other disciplines like active citizenship, technology, biology (especially marine biology), ecology, etc. Of course, other experiments or activities can be added to the path, such as a Kahoot or a board game to foster the students' engagement. Furthermore, this path may be included in a broader review of circular economy models and life cycle sustainability.

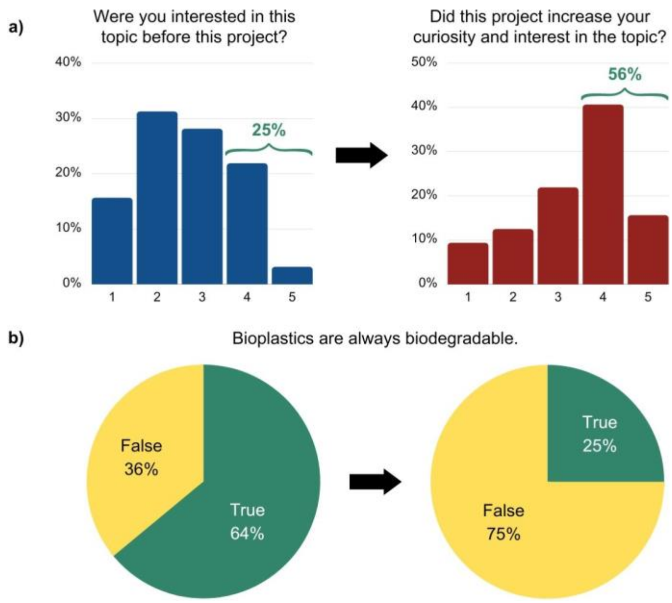


**Figure 4**: **(a)** Comparison of the interest in the topic before and after the learning path (from 1 = "not at all" to 5 = "very much"); **(b)** Answers to the question about bioplastics, before and after the path.

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