Integrating Circular Economy Concepts in School Programmes

Armida Torreggiani[1], Alberto Zanelli[1], Ornella Francioso[2], Lorenzo Forini[3], Alessandra Degli Esposti[1], Renata Lapinska-Viola[1], Emilia Benvenuti[4]

Consiglio Nazionale delle Ricerche(CNR), Istituto per la Sintesi Organica e la Fotoreattività (ISOF), IT[1]
Dipartimento di Scienze e Tecnologie Agro-Alimentari, Università di Bologna, IT[2]
Freelance Gamification Consultant, Bologna, Italy[3]
CNR, Istituto per lo Studio dei Materiali Nano strutturati (ISMN), Italy[4]

Abstract

The established economic practices are dominated by the linear process based on a "take-make-use-dispose" model, having a high cost from an economic, social and environmental point of view. To adopt sustainable strategies with respect to finite resources, and of course to the climate change, it is essential to move towards an alternative model, that can decrease the risk of resource scarcity, responding the unprecedented climate challenges. Thus, Europe is working on the transition towards Circular Economy (CE). But how can the CE key concepts be successfully introduced in high schools, where they are rarely part of curricula? There is a wide range of topics within the theme of circular economy suitable to involve students in thoughtful discussions about habits of consumption, and engage them in concrete actions and in communication work towards society. This is the aim of the European project, Raw Matters Ambassadors @Schools (RM@Schools) which has developed many tools in order to support the introduction of some of the CE key concepts at school and to foster students' interest in science, technology and sustainability. These tools are based on different educational approaches such as gamification and learning by doing and cover a multitude of fields like economy, geology, chemistry, technology, environment, etc. They are are freely available on the e-learning platform of RM@Schools project.

Keywords: *Circular Economy, Lab Experiments, Gamification, Raw Materials, High school, cross-curricular learning*

1. Introduction

Since the 19th century, after the industrial revolution, the large scale production established the linear economy model that can be summarized in three words: take, make and dispose. In the last decades, the awareness of the global warming, due to the abuse of fossil fuels, and the concern for an affordable supply of an increasing number of raw materials to industrialized countries, induced European Union (EU) to start the transition of its economic model from the 'end-of-life' concept with reducing, alternatively reusing, recycling and recovering materials in production and consumption processes with the aim to accomplish sustainable development, creating environmental quality, economic prosperity and social equity, to the benefit of current and future generations. In two words: Circular Economy (CE) [1]. CE is an economic system aimed at eliminating waste and keeping resources within the production cycle. It builds in sustainable design from the inception of a product through the entire life cycle of the product thereby extending the use of materials.

This transition represents a systemic shift that is expected to build long-term resilience, to generate new business and economic opportunities providing environmental and societal benefits [2] in agreement with the Sustainable Development Goals (SDGs) of the United Nation 2030 Agenda [3] and the European Green Deal [4]. The transition to CE can only be conceived in terms of a systemic change, requiring changes in the economic, political and socio-cultural realms. In this transition, education plays a key role and transferring the CE ideas to youngsters is an important task to prepare future generations for the requirements, and challenges of a sustainable development in a prosper society without leaving anybody behind.

CE is a transversal subject that deals with both humanistic and physical sciences, there is a wide range of topics suitable to be faced by a lecture-based approach, but involve students, especially in the age range 15-18, in thoughtful discussions about habits of consumption, and engage them in concrete actions and in communication work towards society. In order to support schools in integrating CE key concepts in the official curricula, some activities were developed by the European project, Raw Matters Ambassadors at Schools (RM@Schools) [6,7] funded by the European Institute for Innovation

and Technology (EIT). These tools are based on different educational approaches from gamification, learning by doing, team working, participatory vision of sustainability, etc [8,9].
All the activities of RM@Schools projects are carried out in a tight cooperation with high school teachers being aware that without their support no long term change in the school programme can be made.
To introduce the CE key concepts at school, the RM@Schools consortium developed specific toolkits including lectures, serious game, lab experiments educational videos, and items to drive discussions or debates. These learning materials cover a multitude of fields like economy, geology, chemistry, technology, environment, etc., and are freely available on the e-learning platform of RM@Schools project [10].

2. Lectures and open discussion

Central to developing an understanding of the CE concept is the development of knowledge, values, attitudes/disposition and behaviour, which are result in positive actions that put the goal for moving towards “zero waste” as a key outcome. The entry point to circular economy education can be through any existing environmental education initiative like energy conservation, waste management, biodiversity education, climate change, etc. The idea is to mirror natural processes to produce resource instead of waste. The critical thinking required is to review for example an objective that we have in our home by asking questions about the possibility and potential of transitioning it into a circular one where waste is designed out right from the start. Students so discover the meaning of “eco-design” and ‘biodegradable’ key terms. For example students can be required to reflect on how to make more sustainable the new capsule-based electric machine for preparing coffee, or how to make more sustainable smart-phones. The lecturer suggests discussion addressing the real need for high-performance devices and the fashion-driven replacement issue (*reduce*), the possibility of giving unwanted item to less demanding users (*reuse*) and *repair*ing the broken ones, so as necessity of a separate WEEE collection to *recycle* immediately the raw materials. Besides the lecturer can show the two smart-phones on the market designed to be sustainable.
Finally, the lecturer can invite the students to work in teams practicing the concepts of the *eco-design* and to pitch another hypothetical device of the everyday-life chosen by pupils (i.e. electric scooter, pursue, etc.). Additional educational modules on the supply chain of raw materials, and on the life cycle of the devices, can drive the team-work [11].

3. Educational Games

In order to make learning more motivating and engaging, serious games are a useful way to introducing the CE concepts and the sustainable use of natural resources at school. For example, in order to increase the awareness of teenagers about the geographical distribution of raw materials (RMs) in the world, their importance for some strategic technologies, and the complexity of their supply to the EU industrial system, a videogame titled “RAWsiko – Materials around us” can be used (Fig. 1). It was created in 2020 by the RM@Schools project during the pandemic COVID crisis to maintain the engagement of students also during lessons at distance and it is suitable for pupils in the age range 10-16 with very basic knowledge on the chemical elements [12]. RAWsiko is set in a fantasy future world where the main producer of critical RMs decides to cut the export to the rest of the planet, and therefore a “RM rush” begins. The players have to fulfil some lists of critical RMs that are key components of different devices that they have to build, so in a funny way it teaches where RMs come from and which devices they are used in, thus it can be of help in opening a dialogue/reflection with youngsters. RAWsiko-Materials around us - is a teaching resource available for free at the site https://arraise.com/rawsiko/.

Fig 1. The game map of RAWsiko - Materials around us, realised on the basis of the real geographical distribution of RMs and one of the objective cards with the RMs necessary to build that device

In order to introduce CE concepts among students in the age range 15-18yrs old, the card game ecoCEO™ can be used [13] The players, act as the Chief of the Executive Office (CEO) of a company that produces electronics in a linear economy scenario managing the personal, making investments to develop a factory of mobile-phones or e-bikes, and selling products. Along the match the shortage of resources, induce the teams to move to circular economy model making their company more resilient. The game introduces the concepts of resource efficiency and substitution, waste recycling, take back and sell for scrap, renting instead of owning, and design for repair. These concepts typical of the circular economy, contribute in different way to gain 'victory points' so, the players learn also the hierarchy of the actions typical of CE. Furthermore, the game aims to stimulate entrepreneurship whereas the competition would enhance the team-working, the problem-solving and the proactive interaction with the other teams.

Fig.2. EcoCEO™ overview picture of the game.

In addition to the card game, further educational materials are available an online platform [14] and provide complementing background information on the subjects addressed in the game, i.e. suggestions for a wide range of linked learning activities, such as suggestions for homework, quizzes, roleplay games, hand-on activities, and experiments to perform in the school laboratory.

4. Experimental Tools

Some lab activities drive students to test directly how it is possible to transform a waste in a new resource by using the curricular knowledge in a simulation of production or recycling processes. For example, acid-base and oxidation-reduction reactions are included in every chemistry curriculum and, where chemistry laboratory is available, they are practiced on artificial samples. One of the lab activities is the recovery of copper from waste electronic boards with a procedures similar to the industrial leaching (Figure 3). This activity is suitable for students skilled in chemistry practice because, after breaking the electronic board, they have to dissolve copper with nitric acid, pore it,

neutralize the solution, reduce copper by zinc powder and dissolve the zinc excess with sulphuric acid. Finally, pore the copper powder and smelt it in a crucible obtaining a small copper ball. Performing this activity gives to students a feeling of doing something useful and practical, used in industry. It gives also a hands-on experience in how much work is needed to recover a metal from a device.
Other hands-on toolkits are available on the e-learning platform of RM@Schools https://rmschools.isof.cnr.it/moodle/ , as shown in Table 1.

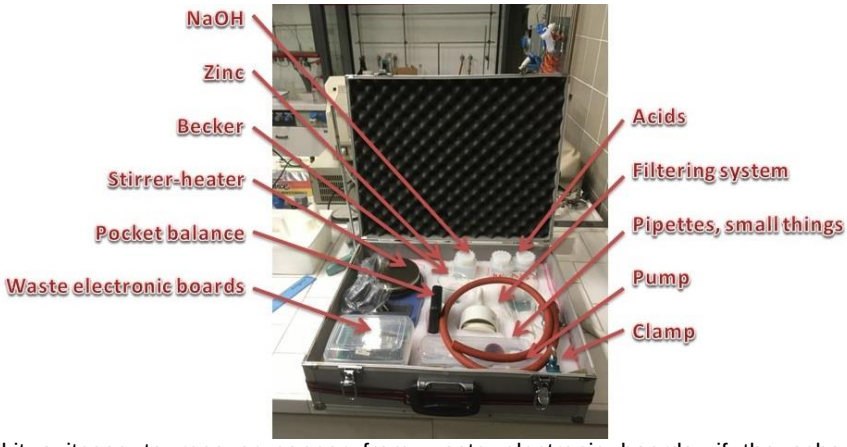

Fig 3. The toolkit suitcase to recover copper from waste electronic boards, if the school has adequate laboratories, the expert can carry a work place for a team of three students.

Table 1. Some hands on activities usefult to introcude CE concepts into the official curricula in the high schools

Toolkit	Age	Learning objectives	Subject links
The Recycling Goose Game	8-13	Students gain a deeper understanding of what can and can't be recycled and how to correctly sort waste for recycling.	Environment, recycling, materials; Active citizenship
Let's make recycling blue	14-19	Students learn chemistry skills and separation techniques.	Chemistry: precipitation, chelation, chemical reactions
Separation of copper and iron - two approaches	16-19	Students reinforce their understanding of solubility and develop skills in reaction equations and qualitative analysis.	Chemistry: precipitation & leaching, acids and bases, cation, anion
Saving copper from waste	10-13	Students reinforce their understanding of solubility and develop skills in reaction equations and qualitative analysis.	Chemistry: single-replacement reactions, redox reactions
Recycling of silicon-based PV modules	14-19	Students learn about importance of photovoltaic (PV) wastes recycling processes in the circular economy world.	Technology: energy saving
The rare earth elements wheel	10-15	Students learn about the metal content, in terms of rare earth elements, in electric electronic equipment (EEE) and waste EEE (WEEE).	Recycling, metal proprieties and applications; Environment
Recycling metallic packaging	16-19	It introduces students to the metallic packaging issues and reinforce skills in chemistry.	Economics; Magnetism; Electrochemistry: reduction potential series, concept of corrosion….

4. Conclusions

CE is a great topic for students to investigate consumerism and habits as well as the interaction between economics, politics, science, technology and product use and development. Activities such as lab experiments and educational games may be useful tools for showing the complexity and interrelation of economy with environmental sustainability issues and can be of help in supporting the integration of some key concepts in school programmes. Thus, students can gain a better

understanding of the balance necessity of the entrepreneurial approach to a resilient business model able to face resource shortages and ecological transitions.

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