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"Don't Throw Away your Mobile!": Pupils' Perception of Raw Materials in Electronics

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Abstract

In this paper we make a re-examination of the messages resulting from the communication products created by pupils of secondary school after participating to a learning paths focused on raw materials and their key role in new electronic technologies. The path is inserted in the "Raw Matter Ambassadors at Schools" project (RM@Schools). The project proposes to 10-17-year old pupils an active learning pathway where students, after attending RM-related classes, are asked to become science communicators and to create dissemination products focused on issues related to RMs. The starting lesson called "Don't throw away your mobile" deals with chemical elements applied in emerging technologies, e.g. Gallium in light emitting diode (LED) illumination, Rare Earth Elements in high efficiency permanent magnets, Indium in flat panel displays and solar cells, etc. All these elements can be found in a mobile phone, from here the name of the lesson. More than 20 dissemination products collected along 4 years of activity are examined. Due to the general character of the lesson, the related dissemination products deal with several topics including ethical and geopolitical issues consequent to the exploitation of natural resources, the analysis of the materials composing mobile and recycling strategies, and the researches on the substitution of critical materials with environmentally friendly alternatives. In addition to the most used communication tools like didactic videos and power point presentations, the pupils' creativity elaborated also stories in the form of comics and cartoons. A detailed analysis allows to understand which are the most important RM-related issues for pupils and identify the most promising strategies for an unbiased communication of the topic.

Keywords*: secondary school, critical raw materials, electronics, research, communication.*

1. Introduction and Methodology

The supply of raw materials is crucial for Europe economy. Since the supply of a certain group of raw materials is a major concern for European industry growth [1], it is important to create a strategy to face this problem with an holistic approach: better exploitation of local resources, substitution of critical raw materials, transition to circular economy. Education of highly skilled professional is a mandatory element in such strategy. For this reason, the European Commission has funded a pool of educational projects, finalized to explain the value of raw materials to society. The project Raw Matters Ambassadors at Schools (RM@Schools) [2] has received funding by the European Institute of Technology (EIT) in the sector of Raw Materials [3] since 2016. It is aimed to raise awareness of the importance of some materials in everyday life in schools and promote the image of science & technology for students aged 10 to 19 years in order to make new professional careers in this sector attractive to youngsters.

The learning pathways proposed in RM@Schools are addressed to a whole class and are featured by a modular structure. The core activities consist in attending a lesson on RM-related issues lead by a researcher and in the creation of a dissemination product inspired by the lesson [4]. Further activities can include either attending a second lesson to learn more or to deepen the previous knowledge, or running an experiment, or visiting a research center, or a company.

In this paper we focus on learning pathways related to raw materials in electronic devices. The core lesson is named "Don't throw away your mobile!". The choice of the title is due to the fact that mobile phones are widely accessible devices which exploit many innovative technologies. The topic is introduced by a google search of "raw materials in electronic devices" which shows the most relevant criticalities in the RM supply chain: scarcity in the Earth crust, provenience, pollution, prices, and ethical issues. Then, we speak about the properties of materials used in various sectors of the semiconductor industry: electronics, photovoltaics, lighting, signal transmission through fiber optics. The main scientific topic of the lesson is the substitution of indium tin oxide (ITO) in transparent

conductive electrodes. Since participation in the project is meant to deepen the curricular knowledge, a "context-based" educational approach is chosen in order to raise interest in the audience [5].
The lesson "don't throw away your mobile!" can be combined with other lessons: i) "Organic materials for photovoltaics", which deals with the use of alternative photoactive materials, instead of (conventional) Silicon, for the fabrication of photovoltaic devices; ii) a lesson about the lifecycle of RMs integrated in electronics, with a focus on circular economy.
The learned contents are re-elaborated by the pupils in autonomy with the class split into groups of 4-5 people. In this paper we make a re-examination of the topics treated in the communication products created by pupils of 13 classes.

2. Results and discussion

2.1 State of the art before taking part in the project

In order to have a better evaluation of the background knowledge among high school students, it is useful to report on the results of a survey prepared by the pupils of two pilot classes, who attended the lesson a couple of weeks in advance with respect to their peers [6]. The survey was made up of 27 questions covering several topics concerning RMs. 433 pupils aged between 13 and 18 years took part in the survey. We can comment some of the answers, see Figure 1. The correct answer to the question "what is the percentage of raw materials imported by Europe?", i.e. "> 80%", was given by 14% of the audience. This indicates that pupils' awareness about criticalities in RM supply was limited before taking part in the project. Pupils favorite solution to RM issues, represented by the question "Which is the best option to invest in?", is Recycling, chosen by 47% of the audience. The focus on recycling is probably related to the feeling of empowerment towards the topic: indeed, recycling is something that most people are used to in everyday life and is perceived as something possible. Other solutions are perceived as a prerogative of scientists and engineers. However, though good recycling practices are widespread for materials like glass, paper and plastics, in most cases electronic devices are bound to lie in a drawer at the end of their lives [18].

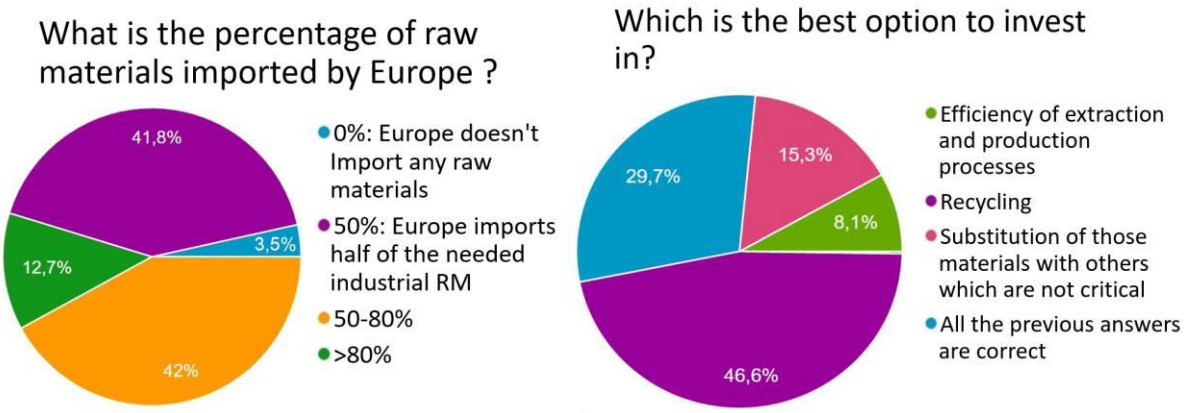


Figure 1. Answers to the survey.

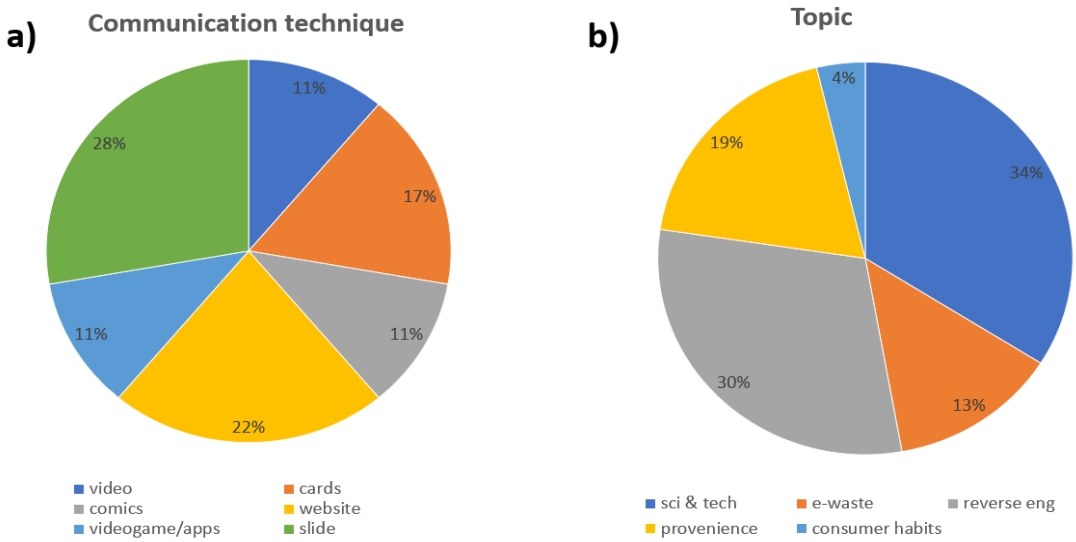
2.2 Dissemination products

Table 1 summarizes the main features of the collected products. The products are grouped by class and each class has been given a progressive number.

Table 1. Title, class number, type of communication technique, age, main topics (including mobile), number of lessons attended by the class, reference number for each product.

title	class nr.	type	age	topic 1	topic 2	mobile Y/N	nr. lessons	ref.
don't throw your mobile... recycle it!	1	poster	11	elements	e-waste	mobile	1	[7]
elements in a mobile	1	poster	11	elements	reverse eng	mobile	1	[8]
waste of materials	1	poster	11	elements	provenience	mobile	1	[9]
don't throw away your mobile	2	slide	11	reverse eng	provenience	mobile	1	[10]
supercell	3	comics	11	e-waste	consumer habits	mobile	1	[11]
do not throw your cellphone (correct disposal)	4	slide	14	e-waste	provenience	mobile	1	[12]
don't thrpw away your phone (pollution, depletion)	4	slide	14	e-waste	sci & tech	mobile	1	[13]
Smartphones	5	slide	15	reverse eng	elements	mobile	1	[14]
padlet	6	website	14	sci & tech	reverse eng	mobile	1	[15]
a tresure in my pocket	7	video	16	provenience	reverse eng	mobile	1	[16]
substitution and miniaturization	7	video	16	sci & tech	substitution		1	[17]
interviews about consumerism	7	video	16	e waste	consumers habits	mobile	1	[18]
galaxy	7	video	16	reverse eng	sci & tech	mobile	1	[19]
light in blue bulbs	8	cards	16	reverse eng	substitution	mobile	2	[20]
PS4	8	cards	16	reverse eng	sci & tech		2	[21]
li battery in mobile	8	cards	16	reverse eng	recycling	mobile	2	[22]
hybrid cars	8	cards/website	16	reverse eng	elements		2	[23]
polaroid	8	cards/website	16	reverse eng			2	[24]
public event san lazzaro	9	event	16	sci & tech	consumer habits		1	[25]
"Have you seen it ?" Looking out for Europium.	10	video	16	sci & tech			3	[26]
magnetic levitation trains	11	cards	16	reverse eng	provenience		2	[27]
lithium battery	11	cards	16	sci & tech	e-waste		2	[28]
lithium battery	11	slide	16	reverse eng	recycling		2	[29]
drugs	11	cards	16	reverse eng			2	[30]
formula 1	11	cards	16	reverse eng	provenience		2	[31]
digital camera	11	cards/website	16	reverse eng	provenience		2	[32]
videogame	12	slide + videogame	16	e-waste	provenience	mobile	1	[33]
element id cards	12	slide/cards	16	reverse eng	provenience	mobile	1	[34]
apps "power electronics"	13	apps	17	sci & tech	provenience		1	[35]

Almost every class made homogeneous works with respect to the communication technique (e.g. video, slide presentation…), owing to two possible reasons: first, the type of output is established in advance by the teacher and the researcher; for example, cards are frequently proposed in order to focus on chemical elements and on working principles of electronic devices. In other cases, the of the means of communication is chosen by the class in order to create homogeneous products which can be grouped: this is the case of the videos produced by class nr.7 and of the padlet produced by class nr. 6. Thus, the output by elaboration techniques, is presented in Figure 3a by grouping the class as a whole. We identified 7 categories of communication techniques. The preferred means of communication are slide presentations, for their ease of realization and versatility, also used as a supporting material for other types of product. Pupils produced also a good number of websites, which are used also to make the presentation of the content (for example of a card) more attractive. The interest for computer-based products is also witnessed by the presence of apps and a videogame. The occurrence of cards appears connected with agreement made by teachers and researchers, and for this reason is to be interpreted as a top-down assignment.



In Table I two columns summarise the main two themes touched by each product.

Figure 3b summarizes the occurrence of each theme. For this analysis each product is counted as a single one. The most recurring topic is “science and technology” referring to products in which physical

or chemical properties of one critical RM are described in order to explain the working principle of a device or to explore the feasibility of their recycling or substitution. In this kind of product, students often talk about graphene which is introduced in the lesson "don't throw away your mobile". Beside graphene, Europium for magnets, and Lithium recycling are treated. The second choice is reverse engineering, i.e. the analysis of the materials constituting an electronic device. Objects such as lithium batteries, hybrid cars, and digital cameras, are ideally dismantled to gather information on the materials they are made up of. Dismantling of mobile phones is mainly chosen by younger students (< 16 year old) who attended only the class "Don't throw away your mobile". The focus on provenance issues is coherent with the poor awareness of Europe dependence on RM import evidenced by the peoples who answered the survey. Many products recognize e-waste recycling and virtuous consumer habits as possible solutions to critical RM issues. Most of these products have a pedagogic intention: people are urged to pay attention to the correct disposal of their technological devices and consumerism is criticized. Though the lesson "don't throw away your mobile" is centered on substitution of critical RMs in emerging technologies, the title induces to consider the end of life of electronic devices. This bias sums to the initial situation depicted by the survey: indeed, before attending the learning pathway, the interviewed pupils showed interest in recycling as a solution that they can afford. Thus, the way pupils speak about recycling in a dissemination product addressed to their peers is coherent with the spirit of the project.

2. Conclusions

We analysed the messages resulting from the communication products created by pupils of secondary schools after participating to learning pathways focused on raw materials and their key role in new technologies and electronic devices. The goal of the lessons was to make pupils aware of the importance of the research in the field of critical raw materials. The fact that most products focus on the properties of elements which make them unique in the production of important electronic devices indicated that the goal has been reached. Moreover, these products indicate that the choice of the context-based approach is effective in involving the students in the search for solutions. The high occurrence of products which deal with mobile phones indicates that probably a combination of the lesson "don't throw away your mobile!" with lessons centered on other topics fosters students' abstraction capability; coupling the lesson with an experiment on ITO substitution can help in fixing the concept of substitution of critical RMs.

3. References

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[9] Waste of materials
[10] Don't throw away your mobile
[11] Supercell
[12] Don't throw your cellphone (correct disposal)
[13] Don't throw away your phone (pollution, depletion)
[14] Smartphones
[15] Padlet
[16] A treasure in my pocket
[17] Substitution and miniaturization
[18] Interviews about consumerism
[19] Galaxy
[20] Light in blue bulbs
[21] PS4
[22] Li battery in mobile
[23] Hybrid cars
[24] Polaroid

[25] Public event in San Lazzaro
[26] “Have you seen it?” Looking for Europium
[27] Magnetic levitation trains
[28] Lithium battery
[29] Lithium battery
[30] Drugs
[31] Formula 1
[32] Digital camera
[33] Videogame
[34] Element ID cards
[35] Apps “power electronics”