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RAWsiko – Materials around us: A Digital Serious Game to Teach about Raw Materials' Importance for the Transition towards a Low-Carbon Economy

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Abstract

Today some raw materials (RMs) have become essential in the manufacturing of common goods and technologies we use every day. Readily accessible RMs, such as rare-earth-elements, indium, neodymium, etc., are important to EU industries and allow the transition towards a low-carbon economy. With the future global resource use projected to double by 2030, addressing raw materials through the entire value chain becomes a priority as well as transferring these ideas to youngsters. "RAWsiko- Materials aroud us" is a serious videogame developed in the framework of Raw Matters Ambassadors at Schools, an European project funded by EIT RawMaterials, with the aim to offer teachers an educational tool able to increase student awareness of the current societal challenges for a sustainable innovation by using an innovative approach. RAWsiko is focused on RMs important for the EU economy but at risk of supply, their distribution in the world, their use in the modern technologies and why access to them is pivotal for European economy. The players can experience the complexity of the raw material supply that occurs behind some everyday life devices such as flat screens and lamps, but also behind the equipment for the transition to the renewable energies such as photovoltaic panels and wind turbines.

RAWsiko can be a support to teach science, technology, and citizenship in a funny way by involving students from 11 to 19 years old and contributing to disseminate the issues of the European Green Deal and the Sustainable Development Goals of the United Nation Agenda 2030.

Such knowledge and awareness among the younger generation is indispensable to secure sustainable success in the European raw materials sector and will help to create a new generation of people skilled in entrepreneurship and raw materials, and respecting our Earth.

Keywords: raw materials, gamification, sustainability, secondary school, cross-curricular learning, serious game

1. Introduction

In human history, every technological progress has always resulted in the use of an increasing number and larger quantities of materials. In the Nineteenth Century, the Industrial Revolution started to produce goods in large scale with a huge use of fossil fuels and raw materials (RMs), but also allowed a large availability of food thanks to new synthetic fertilizers. In fact, the Haber-Bosh process, invented at that age, enabled to produce ammonia from atmospheric nitrogen, whereas other processes enabled to convert bones first, then phosphate rocks in soluble phosphate useful to enhance the food yield per surface unit of the fields. These two aspects induced an exponential growth of the human population in the world.

The last leap occurred at the end of the past millennium with the miniaturization of electronics and the new devices for communication technologies and renewable energies. The accelerating technological innovation, the increasing world population, and the rapid growth of emerging economies are leading to an increasing demand for a great number of RMs. If the current consumption trend does not change, many metals will not be available anymore in the near future.

Today a large number of RMs are becoming a concern for the production of a broad range of goods and devices of the everyday life (i.e. mobile phones, flat screens, fluorescent lamps, etc.), for the transition to renewable energy (i.e. wind turbines and photovoltaic panels) and for strategic industrial

sectors (i.e. telecommunications, defence, nuclear). In particular, the accelerating technological innovation and the fast growth of emerging economies have led to an increasing demand for a great number of metals and minerals that are crucial also for fostering the European economy. Unfortunately, up to now few people know it.
The European Union (EU) does not have sources of these RMs belonging to the non-renewable resources of our planet, and in a near future their foreign supply will be at risk [1] so, the European Commission has launched an initiative to reduce the dependence of its economy from the import of raw materials since 2008 [2]. Three years later the EU published the first list containing 11 critical RMs, that became 20, 27 and 30, respectively in 2014, 2017 and 2020 (Table 1) [3].
The main part of these critical RMs are single chemical elements or their minerals, some of them are groups of metals; in summary the critical RMs represent 46 chemical elements, which is half of the natural ones.

Table 1. List of the critical raw materials 2020

Antimony (Sb)	Germanium (Ge)	Platinum Group Metals (PGMs)*
Baryte ($BaSO_4$)	Hafnium (Hf)	Phosphate rocks (P anions salts)
Bauxite (ore 40% Al)	Heavy Rare Earth Elements (HREEs)[#]	Phosphorus (P)
Beryllium (Be)	Lithium (Li)	Scandium (Sc)
Bismuth (Bi)	Light Rare Earth Elements (LREEs)[°]	Silicon metal (Si)
Borate (B anion salts)	Indium (In)	Strontium (Sr)
Cobalt (Co)	Magnesium (Mg)	Tantalum (Ta)
Coking Coal (mainly C)	Natural Graphite (C)	Titanium (Ti)
Fluorspar (CaF_2)	Natural Rubber $(C_5H_8)_x$	Tungsten (W)
Gallium (Ga)	Niobium (Nb)	Vanadium (V)

*PGMs: Ruthenium (Ru), Rhodium (Rh), Palladium (Pd), Osmium (Os), Iridium (Ir), and Platinum (Pt).
[#]HREEs: Europium (Eu), Gadolinium (Gd), Terbium (Tb), Dysprosium (Dy), Holmium (Ho), Erbium (Er), Thulium (Tm), Ytterbium (Yt), and Lutetium (Lu).
[°]LREEs: Scandium (Sc), Yttrium (Y), Lanthanum (La), Cerium (Ce), Praseodymium (Pr), Neodymium (Nd), Promethium (Pm), and Samarium (Sm).

To overcome the concern for RMs, EU is setting the transition to the circular economy [4] that aims to give a use-life as long as possible to goods promoting the reuse and the recycling of the goods and their components in order to reduce the use of primary RMs. This change from linear to circular economy needs EU citizens to be aware of the criticality of RMs for strategic industrials sector, including the transition to the renewable energy. To trigger the students' interest in raw materials and a sustainable society, the European Institute for Innovation and Technology (EIT), the largest consortium in the raw materials sector worldwide, is funding an educational project titled Raw Matters Ambassadors at Schools (RM@Schools), led by National Research Council of Italy (CNR) in collaboration with 22 partners across Europe, which aims to propose to pupils aged 10 to 18 years an active learning by using different approaches [5,6]. Among them, the use of serious games.
Educational games can fulfil these two aspects, not only with the simulation of experimental activities, but also with role play games [7] that promote curricular knowledge (chemistry, geography, technology) and soft skills as well, very appreciated in the current labour market. Moreover, gamification in education has successfully proven in many contests to increase the engagement of the pupils by means of rewards and feedback [8] and it is used from primary, to middle, to high schools [9,10]. Nowadays, with the wide engagement of pupils and teenagers by new media and communication technology, gamification is moving from the shelf to the web.
Thus to catch the interest of youngsters and open a dialogue/reflection with them a serious videogame focused RMs relevant for technological innovation and the rapid growth of emerging economies was set up and developed. RAWsiko-Materials around us is teaching resource which outlines how teachers can bring these topics, which are relevant to everyone in society, in particular young people, into their lessons (it is available for free at the site: https://arraise.com/rawsiko/).

2. RAWsiko - Materials Around Us.

Here we present an educational videogame titled “RAWsiko – Materials around us” [11] that aims to increase, in a digital and funny way, the awareness of teenagers about the geographical distribution of RMs in the world (Fig. 1), their importance for some strategic technologies, and the complexity of their supply to the EU industrial system.

It is possible to play RAWsiko by using personal computers, tablets or mobile phones downloading a resident free software (Microsoft Windows 8 or higher version, Android) or a web version online through an internet browser. Digital RAWsiko can be played simultaneously by 100 players, and each game can involve 3-5 players that can play on the same device or online in remote mode by the browser, in the last case communications is possible thanks a chat embedded into the game

Fig. 1. Up: the game map of RAWsiko - Materials around us. The map was realised on the basis of the real geographical distribution of RMs (Bottom); **Bottom:** Countries accounting for largest share of global supply of CRMs (source: Geological Survey of Sweeden) [12]

2.1 Where RMs come from and where they got to

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 (as example, Fig. 2). To take control of these RM sources, the players have to move their “mining equipments” in different areas of the world and, if a territory is already exploited by another player, wrest the mining concession from them. The position of the main sources of a selection of critical RMs represents the

real principal mines of these minerals [12] whereas the elements reported in the objective cards represent the most important RM for the production of that technology (see as example Fig. 2).
The game map reproduces in a simplified way the real geographical distribution of RMs since it was realised on the basis of the map distribution of the main RMs supplied by Geological Survey of Sweeden, partner with CNR in the RM@Schools project. In fact, the irregular distribution of some RMs around the globe is one of the reason why a material becomes critical. Supply risk is also determined by geopolitical boundaries. Because of this, resources can be concentrated within individual nations or regions of the globe. This can result in a monopoly and possible supply restrictions due to environmental or regional political factors. Many of the Earth's raw material resources are distributed around the globe, such that criticality may not arise (e.g. Cu, Pb, Zn). Those that are not equally distributed run the risk of supply shortages and disruptions.
By playing RAWsiko and reaching their objectives, the player will learn which critical RMs are involved in the different technologies and where are the main suppliers. For example, wind turbines depend on metals such as LREEs, HREEs and Co, that come from South Africa, Australia and Congo respectively; fertilizers depends from phosphate rocks (PR) and borates (B), coming mainly from Western and Eastern USA respectively. Depending on the number and the criticality of the RMs needed to produce a device, the number of victory points (VPs) of the device increases, presenting to the players the idea of different value chains in the EU economy (Fig.2).

Fig. 2. Some objective cards and the RMs necessary to build them

2.2 Empowering students skills

Together with the knowledge on geography and uses of critical RMs, RAWsiko can increase the awareness among youngsters about the importance of an affordable RM supply for both society and economy, inducing the players to ask themselves: "What can I do to avoid RM shortages?". The answer to this question is in the European Green Deal, the action that aims to make the EU the first continent climatically neutral [13] and in the Circular Economy Action Plan [14], documents that can be translated in easier and more engaging language [15] by the teachers with the help of other teaching materials supplied by the web portal of the Raw Matters Ambassadors at Schools project [6].
On the other hand, the dynamic of the game induces the players to stimulate the so-called "21st century skills" [16], in particular the game stimulates basic skills in ICT (digital competence S.2); readiness to to address new problems from new areas and capacity for quantitative thinking (STEM competence S.4 and S.5); knowledge of vocabulary and ability to understand and interpret concepts, feelings, facts or opinions in oral and written form (multilingual competence S.5 and S.1); ability to effective interaction with other people and to adapt to the changing situation, being flexible and work under pressure (citizen competence S.1 and S.2); independence, motivation, determination and ability to turn idea into action and to plan- manage tasks (cultural awareness and expression competence S.5, S.1 and S.2); and, finally, the ability to identify available opportunities (Personal, social and learning to learn competence S.2).
Furthermore, RAWsiko contributes to achieve the Sustainable Development Goals no. 4 (access to education), no. 12 (responsible consumption and production), and no. 15 (sustainable use of terrestrial ecosystems) [17].

2.3 Further teaching material

The game is supported by a teacher's card that provides teachers with some context around these important issues such as what critical RMs are, how they are classified and some key terminology, in addition to some information about the background of the activity [18]. A student's card introduces

briefly the subject to the potential players, and the instruction to download, install and play the game. In addition, further information to link the game to other curricular subjects, making the activity interdisciplinary are present in these supporting materials.

3. Conclusions

RMs is a great topic for students to investigate politics, policy, consumerism, and the interaction between economics, politics and product use and development. Education and awareness of the uses of raw materials can lead to changes in governance as the values and the voice of citizens are listened to. We hope that students will become more responsible and active citizens when they have gained a better understanding of these complex issues.

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5. References

[1] Vidal, O et al. Nature Geoscience, 6, 2013.
[2] Communication from the Commission to the European Parliament and the Council “The raw materials initiative — meeting our critical needs for growth and jobs in Europe” {SEC(2008) 2741}.
[3] Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions “Critical Raw Materials Resilience: Charting a Path towards greater Security and Sustainability” (COM(2020)474.
[4] EU Commission, Circular Economy Action Plan for a cleaner and more competitive Europe, 2020 (https://ec.europa.eu/environment/circular-economy/pdf/new_circular_economy_action_plan.pdf).
[5] Torreggiani, A.; Zanelli, A. et al. RM@Schools: Fostering Students’ Interest in Raw Materials and a Sustainable Society- Proceedings of the Intern. Conference “The future of education” 2020, 446-150
[6] http://rmschools.eu/
[7] Benvenuti, E.; Forini, L.; Torreggiani, A.; Zanelli A.; Eco-CEO™: Understand the Circular Economy by Playing -Proceedings of the International conference “The future of education 2020” 162-167; https://ecoceo.eu/
[8] Looyestyn, J.; et. al *PLoS ONE*, 2017, 12: e0173403. https://doi.org/10.1371/journal.pone.0173403
[9] At Quest to Learn - https://www.q2l.org/
[10] J. Quinn https://kahoot.com/blog/2017/11/14/kahooters-projected-perform-above-district-norms/ November 14, 2017.
[11] https://arraise.com/rawsiko/
[12] Ladenberger A.; et al. Identification and quantification of secondary CRM resources in Europe – Technical report SCRREEN - Contract Number: 730227 - Solutions for CRitical Raw materials https://www.researchgate.net/publication/325334890_Identification_and_quantification_of_secondary_CRM_resources_in_Europe
[13] Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions “The European Green Deal” COM/2019/640
[14] Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions “Circular Economy Action Plan for a cleaner and more competitive Europe” COM/2020/98
[15] Albertazzi S.; Degli Esposti A.; Torreggiani A.; Zanelli A. Dalla Scuola e dalla Ricerca nuovi linguaggi per parlare di scienza, DA XXV (La diffusione del Sapere) 2, 2009, 30; http//www.daonline.info/archivio/25/pagine/art6_riqua.php (in Italian).
[16] Suto, I. and Eccles H. The Cambridge approach to 21st Century skills: definitions, development and dilemmas for assessment, IAEA Conference, Singapore, 2014.
[17] https://www.un.org/sustainabledevelopment/development-agenda/
[18] https://rmschools.isof.cnr.it/moodle/