Sustainable? Systemic Dis-illusions?

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Abstract

Our students are digital natives, born into a world in which they cannot exist without a digital device. Asking a student for their cell phone is akin to asking a student to give away a limb. The pandemic has amplified the need for these devices in remote settings, each student now has access to not only a smartphone, but also a laptop, thereby increasing their interactions with hi-tech. This has resulted in reducing and perhaps even obsoleting paper writing assignments. Software, new apps and google derived forms have defined the new norm, in the last couple of years. Predictably, anthropogenic demand and consumption for electronic devices has dramatically accelerated, not only in education, but it is seemingly pervasive in all realms modern day living, and even more so in the disciplines of science and technology. As automation increases, so does the demand for sensors. As a humanity, we are alerted to emphatic announcements of extreme weather conditions, climate change and the need to reduce our carbon impact. New technologies have sought materials that can accommodate the repositioning of how we interact, consume and dispose, with our environment. So, what are these materials that are needed that attempt to resolve these concerns? How do they support our daily lives? How do the materials that go into the making of our personal smartphones, laptops and transportation systems, affect everything around us, locally and globally? This unit explores the geopolitical, economic, social and environmental forces at play. High School science students are invited to bring consciousness to their choices and consumption and how each choice and action, seemingly insignificant - is connected, systemic and it has cosmic consequences.

Keywords: sustainability, rare earth metals, critical metals, systems

Unit Content

Introduction

Living without a cell phone is unimaginable for a High School student. Most students can identify plastic and metal, glass or even silicon as one of the elements that goes into the making of a cell phone. This unit delves into the uses of the group considered the Rare Earth Metals found on the Periodic Table, and the Critical Minerals/Metals as defined by the United States Geological Survey (USGS). Why are these so called rare and critical materials/metals considered to be, as such? Why are they needed? How are they sourced, used and disposed? What do they do – and how are they used in the making of our devices? Where on earth are they found, and who has control and power

over these earthly resources? What forces enable us to have, or not these tools and gadgets. Can we consciously consider, what it takes to bring comfort and convenience to our daily lives? Students are invited to uncover these realities.

Background

We live in a time that has seen intense change in a very short period of time. There are daily local and global announcements in the news of the pandemic, climate related disasters, companies creating technological disruptions, increased citizen activism, economic and environmental volatility. We are more informed now than ever before. We are changing consumption and habits rapidly so as to adapt. What has made that - possible? What devices are we using that makes this information available in real-time? What devices/tools are we consciously, or unconsciously assimilating into our lives? What are the materials and elements that are used that go into the making of the smartphone we hold in our hands? We see the color and light, touch the screen and switch applications – is it mindlessly? Can we even pronounce and spell the name of the material that goes into the making of the smartphone, that we cannot live - without? Why have we not considered these elements so closely – before?

In this unit students will be choosing one rare/critical metal element from the Periodic Table to investigate. Through the lessons they will be introduced to and focus on the element, how it is sourced, used, and disposed. Students will research where the resource is located, the geopolitical, economic and environmental impact that goes into having the element made available, to make the devices we use, daily.

The standards used in the compilation of this unit are the Pennsylvania Science and Technical Subjects Standards: **(C.3.5.9-10A),** Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions, and **(CC.3.5.11-12.H),** Evaluate the hypotheses, data analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. The connected Next Generation Science Standards (NGSS, 2021) Standard **HS-ESS2-2** Earth's Systems: Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth systems.

Content Objectives

Rare Earth Metals

Rare Earth Metals – are really not that rare! They can be found in nature although they are challenging to extract in that these elements have a significant impact on the water, soil and air systems in their environments. The 'Rare Earths' are a group of 17 elements significant in the manufacture of many of our modern hi-tech commercial and consumer

products. For example, Yttrium, Terbium, Gadolinium and Europium are used in the making of computer and television screens as they are capable of giving off different colors. Gadolinium is also used in more efficient refrigeration systems, X-ray and MRI scanning systems. Lanthanum is used in lighting systems for cinematic projections and studio lighting. It is also used in telescope and camera lenses. Consider this, before smartphones, in the recent past, cellphones were not all equipped with cameras! Neodymium is not only used in the manufacture of hybrid cars and wind turbines, but also in the making of powerful magnets enabling the making of miniscule yet powerful loudspeakers and computer hard drives. Lanthanum along with Cerium is involved in the processing and of refining crude oil. Cerium is also used in the catalytic converters of cars enabling them to run at high temperatures and reducing carbon emissions. Praseodymium is used to make visors for welders and glassmakers. Aircraft engines use this element due to its strength.

Critical Minerals

According to AmericanGeoSciences.org, Critical Minerals are essential for society and demand has increased with the use of high tech. devices for personal and commercial use such as smartphones, solar panels and tablets. VisualCapitalist.com states that vital metals used to build devices are at risk due to factors that include geopolitical issues.

Teaching Strategies

Direct Instruction: Teachers in the first 15-20 minutes of the lesson, will introduce an idea or topic for students to consider, further develop and investigate. This enables student to initiate their adventure with a focus and guided starting point, with structured guidance. This supports all students in an inclusive learning space, and enables students to amplify sections that intrigue them.

Project Based Learning: Teachers introduce an idea to students, students then research and gather credible information using guiding questions. During the active investigation and research learning time, the teacher will facilitate the learning by listening to students group discussions and conversations as they evaluate and select what they choose to embrace. At the end of the unit, students will present their discoveries, reflections and learning, to their peers.

Photo Images: At the start of the unit, students use this visual tool to identify items of daily use. It forms a more pragmatic vehicle to the show and tell approach.

Observe and Reflect: This enables students to step back from the information, evaluate it with minimal reaction and reflect on situations. This strategy is used in an attempt to encourage students to approach discussions and conversations with claims, evidence and

reasoning, and minimize students responding to situations with approaches of I believe, or I like.

Classroom Activities

Lesson #1

What is sustainability? Looking at the interacting connecting factors that impact our survival.

The first lesson is designed to get students thinking about the concept of sustainability, and how it is defined. What it means and how it interacts with the choices we make with our daily actions, and the products we buy and use. It is the precursor to recognizing choices that are made knowing or unknowingly as we interact with our environment.

Objective: Students will be able to describe the factors of sustainability that impacts modern day living.

1/ Teacher will assign the following tasks for students: "Find 3 objects that you or a person in your household uses daily. Take pictures or create a list to share in class."

2/ Students will share the different products used daily. Teacher steers and amplifies mention of electronic devices such as cell phones, laptops and TVs. Teacher will then ask students, "Take one of your electronic devices and in pairs or small groups to determine what materials (elements from the periodic table) that went into the making of the product.

3/ Teacher will

a) Create a list on a smartboard and mark off the number of times students mention a particular object. It is anticipated that cell phones and laptops with have the highest count.
b) Show images of different materials used to make a cell phone using infographics.
c) Ask students to choose one of the elements used in the making of the smartphone, and complete a KWL (Know, Want to Know, Learned) chart.
d) Ask students to share their findings and evaluate if the element is sustainable using a CER (Claim, Evidence, Reasoning) chart.

Students will:

a) Complete a KWL chart about that element.

The students need to consider where the element came from to make it, with web research.
And what happens to the product after it is used, and disposed.

b) Students will evaluable if their element is sustainable, and share their CER with discussion to the class.
   - Is the element sustainable?

4/ Teacher will ask students to complete a 3-2-1 using complete sentences stating:

- 3 ideas that they found interesting from the activity.
- 2 issues they are now wondering about, and
- 1 question they would want to research and further investigate.

Lesson #2

In this lesson students will develop a background understanding of the group termed Rare Earth Metals on the Periodic Table.

Objective: Students will be able to identify rare earth metals and their uses in everyday products.

Teacher will:

Define and identify Rare Earth Metals on the Periodic Table, and ask students in groups of 4 to choose one from the following list:

Lanthanum, Cerium, Praseodymium, Neodymium, Promethium, Samarium, Europium, Gadolinium, Terbium, Dysprosium, Holmium, Erbium, Thulium, Ytterbium, Lutetium

Students will:

Take their chosen element and research and use a poster board or large sheet of paper to write and draw their findings, discoveries, concerns and questions.

Guiding points for students:

- State the element and symbol, how and when was it discovered
- How it the element sourced and used?
- What is the element's chemical and physical properties?
- Why is this element important, is there an alternative that can serve the same purpose?

Share their poster presentation with the whole class.

Students will complete an exit ticket that states their reflection on something they found intriguing, and thoughts on the activity that prompt a question in their mind.

Lesson #3

Following the introduction of the Rare Earth Metals students will map out and investigate where these resources are located, mined and extracted. They will look into the countries and political influence in accessing the material.

Objective: Students will be able to compare critical metals and the geopolitical impact on global supply systems.

Teacher will:

Ask define and display a list of Critical Metals to students. Students will choose one from the list and research the element and "Create a Google slide Deck or Power Point.

Students will:

b) Use web research and images to denote the Name, Symbol, location on the periodic table, the periodic group it belongs to and the general characteristics of that periodic group.
c) Explain:
    - How much of that element is found on earth?
    - Where it is geographically located?
    - How is it extracted and processed?
    - What are the applications for what is it used?
    - Which countries export and import this material and in what quantities?
    - The final slide needs to indicate references/citations on the information gathered.

Lesson #4

This lesson is designed to have students consider the supply and demand of the material and the influences that impact the cost and prices of products.

Objective: Students will be able to compare critical metals and their economic impact on global supply systems.

Teacher will:

Ask students to continue their research and develop their slide deck presentations and to consider the economic impact of supply and demand.

Students will:

Continue the research on the Critical Metal element, and build their slide decks to consider and explain:

- Which country has the material, and which country wants it and why?
- Who or what institution guides the pricing?
- What are the costs involved for extraction, energy and transportation?
- The final slide needs to indicate references/citations on the information gathered.

Lesson #5

After students have considered the financial costs in bringing a product into their hands, this lesson encourages students to consider the ecological impact from the immediate communities from which resources are sourced, what happens during consumption, and then disposal.

Objective: Students will be able to compare critical metals and their environmental impact on ecological systems.

Teacher will:

Display article explaining the environmental impact of Lithium mining students to continue their research and develop their slide deck presentations and to consider the environmental impact of their chosen element when sourced, and when the product is disposed after it is used. Here the teacher shares details of batteries used as a solution to decrease carbon emissions through the use of Fossil Fuels in an effort to counter climate change.

Students will continue the research on the Critical Metal element, and build their slide decks to consider:

- What plants, animals and communities were impacted when the element was extracted?
- How did it affect people in the area with respect to their water, soil and air before and after the resource was extracted/sourced?
- After the element was used in a product, how and where is it disposed?

- The final slide needs to indicate references/citations on the information gathered.

Lesson #6

At this point of the unit students have journeyed through a variety of pathways that converge to make a product available for use, and the subsequent systemic interactions that reverberate beyond their immediate space. At this point, students are asked to reflect and share their perspectives and propose possible solutions to their concerns and perceived problems.

Objective: Students will evaluate trash and how they can provide alternatives in their own lives and communities.

Teacher will:

- Explain the waste management hierarchy and will give an example of the types and quantity of electronic materials that are disposed, and the possible solutions and challenges associated with recycling.
- Ask students to continue their research and develop their slide deck presentations and to consider the processes involved with retrieving and recycling a product that uses their chosen Critical Metal element.

Students will:

Continue the research on the Critical Metal element, and build their slide decks to consider:

- Can it be recycled, what are the processes and costs involved?
- How does the element react or breakdown and how long does it take?
- Is it safe or toxic, and what other materials may it react with?
- Identify two possible solutions to better handling the final outcome of the product after use.
- The final slide needs to indicate references/citations on the information gathered.

Lesson #7

In this lesson students will share their discoveries with their peers, using selected images and videos to punctuate their perspectives and proposals from their project learnings.

Teacher will schedule student groups allowing 10-15 min. presentations reminding students that all students in the group would need to participate. Will share the presentation rubric, and after each presentation invite peers from the audience to share feedback with at least 2 “Glows,” and 2 “Grows.”

Students will present their research findings and proposals using their slide deck to the whole class.

Resources

The following four websites support teaching and learning for the first lesson and enables us to consider the word sustainability and how specific aspects are accentuated depending on the institution and the author.

https://www.environmentalscience.org/sustainability

https://www.epa.gov/sustainability/sustainability-and-us-epa

https://www.sustain.ucla.edu/what-is-sustainability/

https://www.nrdc.org/experts/eileen-quigley/big-business-and-latest-trends-sustainability

The websites below range from a site that has user-friendly overviews of a variety of products used daily, and the elemental components. It makes it accessible and inclusive for first time chemistry experiences. There are videos and sites that inform teachers and learners of the rare earth metals and uses for the second lesson.
https://www.compoundchem.com/2014/02/19/the-chemical-elements-of-a-smartphone/
https://www.youtube.com/watch?v=QiQoMDZGCs4

https://pubs.usgs.gov/fs/2014/3078/pdf/fs2014-3078.pdf

https://qz.com/emails/quartz-obsession/2093118/?utm_source=email&utm_medium=quartz-obsession&utm_content=2bbafb59-51e8-11ec-9676-4242dc9d9406

https://web.mit.edu/12.000/www/m2016/finalwebsite/elements/raremetals.html

https://www.youtube.com/watch?v=88jpgxSRVZU

https://www.youtube.com/watch?v=Z6HYAlSdR2g

https://web.mit.edu/12.000/www/m2016/finalwebsite/elements/index.html

Lesson 3 – Critical Minerals

For the third lesson the following websites shed light on the geopolitical issues that make certain elements critical, for not only the United States but also for global economies.

https://www.americangeosciences.org/critical-issues/maps/visualization-mineral-resources-everyday-objects

https://www.visualcapitalist.com/visualizing-the-critical-metals-in-a-smartphone/

https://www.usgs.gov/news/interior-releases-2018-s-final-list-35-minerals-deemed-critical-us-national-security-and

https://www.americangeosciences.org/critical-issues/faq/what-are-rare-earth-elements-and-why-are-they-important

https://japantoday.com/category/tech/rare-earth-metals-supply-the-next-microchip-crisis

https://www.youtube.com/watch?v=gyH_PvLZoD0

https://qz.com/2098539/eu-japan-dont-want-us-tariffs-on-ndfeb-rare-earth-magnets/?utm_source=email&utm_medium=daily-brief&utm_content=f3f1187c-5e57-11ec-aaa2-966f5c8b6330

https://www.nytimes.com/2021/12/03/world/congo-cobalt-albert-yuma-mulimbi.html?action=click&module=Well&pgtype=Homepage&section=Climate%20and%20Environment

https://www.usgs.gov/media/images/us-minerals-net-import-reliance-2020

https://www.youtube.com/watch?v=CW4TnJDIQUw

https://qz.com/2065130/can-us-imports-of-rare-earth-magnets-harm-its-national-security/

https://qz.com/1988240/rare-earths-mining-takes-center-stage-in-greenland-elections/?utm_source=email&utm_medium=quartz-obsession&utm_content=af263340-4b9d-11ec-954c-3237793624ba&utm_source=email&utm_medium=quartz-obsession&utm_content=af263340-4b9d-11ec-954c-3237793624ba

The following websites for the fourth lesson enable students to expand their understanding of the economic factors affecting alternative energy sources that attempt to combat climate change.

https://www.youtube.com/watch?v=T7pusAWBCoE

https://www.bloomberg.com/news/articles/2021-12-14/the-black-forest-holds-a-secret-to-making-electric-cars-greener?cmpid=BBD121521_MKT&utm_medium=email&utm_source=newsletter&utm_term=211215&utm_campaign=markets

https://qz.com/2062525/how-china-keeps-a-grip-on-the-rare-earth-metal-industry/

https://www.reuters.com/business/energy/china-hikes-2021-rare-earth-quotas-by-20-record-highs-2021-09-30/

https://www.youtube.com/watch?v=UvQMiqqzcZE

https://www.youtube.com/watch?v=4fJAL8sNndc

Focusing on the environmental implications the websites below look for alternatives to the alternatives, given the impact that excavating rare earth metals have on the environment in the fifth lesson.

https://www.sciencenews.org/article/search-new-geologic-sources-lithium-could-power-clean-future

https://techxplore.com/news/2021-12-battery-technology-closer-reality-discovery.html

https://web.mit.edu/12.000/www/m2016/finalwebsite/problems/environment.html

https://www.theguardian.com/world/2021/dec/05/rio-tinto-lithium-mine-thousands-of-protesters-block-roads-across-serbia

https://www.theguardian.com/us-news/2021/dec/02/thacker-pass-lithium-mine-fight-save-sacred-land-nevada

https://www.theguardian.com/environment/2021/may/10/recycling-rare-metals-climate-green-technology

https://www.nytimes.com/2021/11/29/world/congo-cobalt-albert-yuma-mulimbi.html?action=click&module=RelatedLinks&pgtype=Article

As mankind progresses, we attempt to consider the natural cycles such as carbon, water, nitrogen, and our quest continues to emulate nature, without disrespecting the resources on this planet, the following websites take steps towards this idea.

https://axil-is.com/waste-management-hierarchy/

https://web.mit.edu/12.000/www/m2016/finalwebsite/solutions/recycling.html

https://www.compoundchem.com/2015/09/15/recycling-phone-elements/

https://www.youtube.com/watch?v=aWNalOpwpDA

https://www.theguardian.com/environment/2021/may/10/recycling-rare-metals-climate-green-technology

The following links can be used to create a presentation rubric for students based on the teacher's particular student population.

https://link.springer.com/article/10.1007/s11423-021-10030-7/figures/1

https://www.teacherspayteachers.com/Product/Google-Slide-Presentation-Rubric-4914418

https://www.teacherspayteachers.com/Product/FREEBIE-Presentation-Rubric-EDITABLE-in-Google-Docs-810784

Appendix

Pennsylvania State Standard

C.3.5.9-10A Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions.

CC.3.5.11-12.H Evaluate the hypotheses, data analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information

Next Generation Science Standards

HS-ESS2-2 Earth's Systems: Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth systems.

Summary

This unit attempts to engage students into looking at our world, the conveniences, problems and solutions we choose in our modern day living. It provokes students into thinking not only about the element or material as it stands as an isolated entity, but rather how systemically it is connected to so many other situations and decisions that flow downstream.