Critical Metals and Their Real-World Applications

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Abstract

How are humankind's needs changing? How do our perceived needs impact the world around us? What is ethical consumption? If we continue to rely on fossil fuels, our planet will degrade unrecognizably. Renewable energy is a paradoxical solution to the problem of climate change if we use unnecessarily harmful practices to extract the necessary materials. Students will learn what distinguishes a critical metal, how we mine/extract these metals, how the processes and byproducts impact the environment, how the metals move through supply chains around the world, how those metals are applied in various industries/products, and how we use/re-use/dispose of those metals. Students will compare and contrast different forms of energy in order to lay a foundation for the inevitability of a battery-based renewable energy system across the planet. They will also gain a general understanding of how rechargeable batteries work, and connect this understanding to what they already know about storing and converting energy. They will practice researching independently, and presenting their findings to a community of peers. The expectation is that students will come away from their studies with a personal commitment to consuming less and reusing more, and a mindset that our choices as individuals as a population can make a difference.

Unit Content

If we do not understand how to research and evaluate data, then we are ill-equipped to make life decisions that would be impacted by that information (such as purchasing materials, using energy, voting, taking conservative or activist stances, etc). Students develop their skills and knowledge slowly, with a gradual release method that transitions from a teacher-provided resources and storyline to a research project based on grade-level content and complex, open-ended questions.

Day 1 begins with *DR Congo Miners Work in Treacherous Conditions*, in which Congolese cobalt miners testify that they put themselves in harm's way because there is no other employment available. Chinese companies have taken over most operations. The machines and scales that measure the amount of the unique mineral that each worker brings up the shaft are allegedly rigged, and if no cobalt is found, then they don't get paid at all. The average take-home pay is six dollars per diem. This is followed by the *Underground Drilling and Blasting Training Video*, which details an industrial process in mining, in which holes are drilled in rock, explosives are placed in the holes, and a chemical reaction creates enough pressure to break apart huge swaths of stone. Storage, movement, and firing of explosives must follow safety protocols, and sites remain hazardous afterward because of fumes and instability. *Ore deposits are a source of valuable metals and minerals* explains that ore is a nonrenewable resource. It's a mixture of rock and metal, which must first be taken from the earth, next pulverized, and then either separated into its disparate components via smelting (which uses high temperatures, and sometimes chemicals) or electrolysis (which uses an electrified acid bath). Students learn that ore either falls to earth as space debris or is formed in internal processes (geologic), hydrothermal processes (through slow accumulation of minerals around deep sea vents), and surficial processes (such as erosion). Clearly, there is more to metals than we knew.

Day 2 starts with *The Periodic Table*, which states that “Metals are generally shiny, malleable elements that conduct heat and electricity well. Most are solid at room temperature. In reactions metals tend to form positive ions. Metalloids have properties that are in between those of metals and non-metals.” The Socratica video adds ductility to this list of physical properties, and attributes these metallic qualities to the mobility of metals’ electrons (through vibration around or flow between atoms) and weak (and thus flexible) attractions/repulsions and bonds between atoms in pure crystalline form. Metals absorb and release light energy easily, hence their reflectivity. Their colors show which wavelengths of light are not absorbed. Students explore properties by rotating through stations, observing, and recording data: luster by shining a light on the metals in a relatively dark area, malleability by hammering wires, ductility by bending wires, conduction of heat by heating the wire for a set time and measuring the temperature increase, and conduction of electricity with an ohmmeter or multimeter. A simple chart (see the sample below) will aid in data collection for students:

	Aluminum	Iron	Copper
Luster			
Malleability			
Ductility			
Conduction of heat			
Conduction of electricity			

On Day 3, *U.S.-China trade: What are rare-earth metals and what's the dispute?* offers this answer to its title: “Rare earths are not actually very rare. They can be found across the Earth's crust. However, they are often in low concentrations and are difficult and expensive to mine. The process can also damage the environment, with ecosystems put at risk by pit mining, the release of metal byproducts from refineries, and water contamination from particles being dumped during waste disposal. China is by far the world's largest producer of rare earths and accounts for about 70 percent of global production. The country has some 37 percent of global reserves.” Students also learn that these elements are sought after as necessary components of much of the technology we rely upon, and after the 2019 trade war, we have been looking for alternative sources. *Rare Earth Elements* explains that extracting and refining rare earth elements creates toxic waste even in the “cleanest” operations. Even under American regulations, disposing of this waste is a measure of containment, not elimination. Nightline describes lithium’s origins and destinations, and how we will soon be expected to produce ten times more of the stuff than we do right now. It can be mined as a solid or liquid, and lots of water (which in itself is critical) is needed in the process. Here in the US, and in Chile (where much of the global supply is sourced), pools of mineral-rich solution are left to evaporate in the sun… and perhaps leach into the soil. Wildlife (some of it critically endangered) could be destroyed by open-pit mining. We must measure risks in degrees.

The jigsaw activity on Day 4 is a vehicle for background knowledge-building, in which small groups of students study specific topics and share them with the class. The *Drilling down into petroleum's impact on life on Earth* group will find that petroleum comes from the remains of plants and photosynthetic protists, chemically transformed over millions of years and many processes. We get it by drilling into reservoirs in the earth, we store and measure it in barrels, and oil reserves are now one measure of a government's wealth. Though oil powers our current economy through combustion reactions, the carbon dioxide products disrupt a balance in our biosphere, while other products cause pollution. The *Coal is about to be toppled as the nation's leading power source, EIA says* source explains that coal used to be the largest generator of electricity, but has since been superseded by natural gas. Further research would tell that both are fossil fuels, are either drilled or mined, and must be stored carefully because of their flammability. We use them for power, and they have the same basic environmental concerns as petroleum. The *What is Nuclear Energy?* video says that nuclear energy is stored in the nuclei of atoms. When atoms are split apart in nuclear fission or joined in nuclear fusion, a massive amount of energy is released. Uranium is mined from the earth, formed into pellets, placed in nuclear reactors, and atoms are split apart therein in chain reactions. Heat energy is released and transferred to water, which vaporizes and pushes turbines which in turn drive electric generators, with zero greenhouse gas emissions. The used pellets are radioactive, and remain toxic for millennia, so their disposal is carefully regulated. The *Types of renewable energy* reading profiles solar, wind, geothermal, biomass, hydroelectric and other sustainable energy sources. We capture these forms of energy either actively or passively by building PV cells, solar panels, wind turbines, heat pumps, steam-powered electric generators, biomass briquette manufacturers, and hydroelectric dams. All of this infrastructure serves to convert one form of energy into another, which is either used immediately or stored somehow (we will discuss batteries later). Renewable resources are important to us because they free us from fossil fuels, but they often come with their own drawbacks (such as inconsistent availability or danger to living organisms). *Step-by-step guide and research rescue: Evaluating Credibility* will be a resource students can turn to throughout the year to find clear and true information efficiently.

Day 5's photos from CBS illustrated what the world looked like when we used less fossil fuels, while satellite imagery from CNN served as the contrast: when we resumed regular work and travel, the globe succumbed to pollution once again. *CO2 in the Ice Core Record* introduces the National Ice Core Lab and its role as a library of our planet's climate history. Though there have been periods of high carbon dioxide in the air during interglacial periods, and low carbon dioxide in the air during ice ages, this was part of a natural pattern. The rising levels of greenhouse gasses since the Industrial Revolution do not fit that pattern, and have not been seen in 400,000 years. The World Economic Forum article imagines a worldwide sustainable energy grid in the year 2050, which would minimize costs, lessen climate change, and cut pollution. If those in power do not act quickly, the consequences to the environment and global health will be dire. Utility Dive details our current predicament of high demand (for the minerals we need for this sustainable future) and low supply (because of the inverse relationship between China's growing mining/processing capabilities and the readiness to do the same in other parts of the world). The US is behind in both infrastructure and human resources. We'll need a lot of policy changes to encourage new approaches and growth in the critical metals sector.

The iPhone battery test launches Day 6, and reminds students that we can only compare accurately when we take variables into account. The TEDEd video explains how the first battery was created, how rechargeable batteries work (electrons flowing from one material to another while the battery is being used, and then flowing back when the battery is being charged), why these batteries' storage capacity fades over time (the metal inside loses its structural integrity and fails to oxidize), and what batteries of the future might look and act like. *Electric Cars and Batteries: How Will the World Produce Enough?* posits that as our needs transition from fuel to critical minerals, we will need to work with less materials and recycle more, specifically in regards to lithium, which is now fairly cheap and accessible. A more efficient battery structure can be managed with a more energy-dense, high-performance, cathode design (implementing cobalt or nickel, or rock salts, perhaps). If governments and companies shore up their recycling programs, then the current processes (shredding batteries, then smelting the metals or separating them with acids, then collecting the solid precipitates) could be replaced with cutting-edge techniques (like reusing unbroken cathode crystals or disassembling batteries using ultrasound). The more batteries we use, the more likely we are to seek zero-waste solutions. *The 17 Goals* "recognize that ending poverty and other deprivations must go hand-in-hand with strategies that improve health and education, reduce inequality, and spur economic growth – all while tackling climate change and working to preserve our oceans and forests." For students, they provide a moral litmus test for all future energy solutions.

The summative assessment's only predicted contents are the research topics: atomic structure, extraction processes, supply chain, known observable properties, potential energy storage, use and disposal, and impacts to society and the environment. Students can do as much with these subjects and a specific critical metal as they wish to, and when they finally present what they've learned to the classroom scientific community, they will have worked their way through a guided inquiry process.

Teaching Strategies

Before this unit, students will have studied basic chemistry, thermodynamics, forces and motion (including electromagnetism), and kinetic-potential energy conversions. After this unit, they will study light and sound. They will be familiar with the practices of "doing science" (asking questions, modeling, conducting investigations, constructing explanations, and engaging in argument from evidence). They will have completed several research-based projects, and know how to use inquiry methods and present findings.

We will start by viewing the anchoring phenomena of artisanal mining and open-pit blasting. This imagery should spark students' curiosity, and provide a foundation for the unit, beginning with what they notice and wonder. The essential questions we introduce will focus our explorations while allowing for multiple, evidence-based answers that build upon each other. The word-phrase-sentence method of summarization gives students a structure that is both specific and individualized. Then, we will learn some basic information of what metals are, and how we separate them from ore. When students catalog metals by their properties, they practice vocabulary within a real-world context. Students will be introduced to critical metals via reading and writing as individuals, and speaking and listening in groups. Then, we will look at rare earth elements, connect them to what we already know about chemistry, and how our international landscape shapes the way we access them. We will think about the ethical, environmental, and political issues that we already recognize, and come up with original driving questions, which are meant to be answered through inquiry. Guided class discussion will add depth to content knowledge. When we examine the credibility of sources, we assess our own ability to tell facts from opinion, neutral information from that which fits an agenda. This is an important skill for all young researchers to use.

When the jigsaw strategy is used, students research and present their work about various renewable and nonrenewable resources; in effect, the teacher is merely the sharer of materials, and the students teach each other. We will analyze data to find links between climate change and different forms of energy usage, and then we will use concept maps to visualize and explain those links. In this way, students draw connections and support their own arguments. We will model how rechargeable batteries work. Students keep using notice and wonder charts to practice mindful observation and questioning. We will see that advancements in science and technology have far-reaching implications, and that the key to a bright future is adhering as much as possible to sustainable development goals. We will engage in evidence-based scientific arguments to evaluate the merits of various solutions to the current energy crisis. Students will use various graphic organizers to facilitate this knowledge-building in their science notebooks. This understanding may have answered some of the questions on our driving question board. Recognizing which questions have and have not gotten responses will underline the ongoing nature of scientific study.

Then, students will be provided with a research project description with which to explore a particular metal and its impact on society and the environment. They will make connections between our new information and our previous understandings about physical and chemical properties of elements, as well as the purpose of batteries and/or specific metals in energy applications. They will see that criticality is a cycle of cause and effect in our modern world.

Classroom Activities

Established Goals

- MS-PS1-1 Matter and its Interactions
- Develop models to describe the atomic composition of simple molecules and extended structures.
- MS-PS1-4 Matter and its Interactions
- Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed.
- MS-PS3-2 Energy
- Develop a model to describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system.
- MS-ESS3-4 Earth and Human Activity
- Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems.

- **S8.C.2.1.1** Distinguish among forms of energy (e.g., electrical, mechanical, chemical, light, sound, nuclear) and sources of energy (i.e., renewable and nonrenewable energy)
- **S8.C.2.1.3** Describe how one form of energy (e.g., electrical, mechanical, chemical, light, sound, nuclear) can be converted into a different form of energy.
- **S8.C.2.2.2** Compare the time span of renewability for fossil fuels and the time span of renewability for alternative fuels.
- **S8.C.2.2.3** Describe the waste (i.e., kind and quantity) derived from the use of renewable and nonrenewable resources and their potential impact on the environment.

Transfer

Students will be able to independently use their learning to effectively research, present, and...

- Model a critical metal's atomic structure, as well as its extraction processes and supply chains, and list all phase change temperatures of the critical element.
- Explain how interactions of objects affect how potential energy is stored in the critical element.
- Explain some extraction processes and three of the element's uses by humans. Explain how a critical metal's consumption impacts Earth's systems.

Meaning

Understandings

We will need critical metals in the future, but we also need a healthy and stable environment and society. Nonrenewable resources are not inherently "bad." What is actually problematic are our methods of supply and distribution, since not everyone has or uses these resources, but almost everyone wants them. Reusing, recycling, and reducing our use of these metals is imperative as we move away from fossil fuels.

Essential Questions

How are humankind's needs changing?

How do our perceived needs impact the world around us?

What is ethical consumption?

Acquisition of Knowledge and Skill

Students will know…

A material’s atomic structure determines its physical and chemical functions.

Batteries store and release energy.

We convert energy all the time.

Individual choices impact collective energy and resource consumption.

There are direct relationships between our use of energy and our use of resources. The use of resources has reverberations in the natural world.

Students will be skilled at…

Evaluating the goals and intended audience of published research.

Reading charts and graphs.

Comparing and contrasting.

Determining cause and effect.

Developing models.

Arguing from evidence.

Evaluative Criteria

Performance is judged in terms of…

A rubric (see appendix for related standards) will be used to evaluate the transfer task, writing prompts will formatively assess standard **MS-ESS3-4**, and notebook, discussion, and group work will formatively assess standards **MS-PS3-2** and **MS-PS1-4**.

Assessment Evidence

Transfer Task(s)

Students will conduct and present a guided research product on a specific critical metal.

Other Evidence

NewsELA writing prompts and quizzes, science notebook check (for comprehensive notes and graphic organizers), discussion participation (evidence of understanding and misconceptions), and group work.

Where is this leading to?

A unit on light energy, in which students will understand that the sun’s rays are our one truly renewable resource. If we do not get a handle on fossil fuels, though, the greenhouse effect will not allow the sun’s heat energy to escape, and this will be a huge challenge for future generations.

Activities and Notes

Day 1

Set up a Notice-Wonder chart in your science notebooks. Watch *DR Congo Miners Work in Treacherous Conditions* and *Underground Drilling and Blasting Training Video - ACG.* Share out: What are some things that caught your attention about these mining practices? What do you wonder about it? Students may comment on human and environmental impacts. Then pose the questions: *Why do we mine for critical metals? Why are they so important for our energy needs? What are the costs and benefits of extracting these metals?* Explain to students that we will be exploring this content deeply in the upcoming unit. We’ll start with learning a little bit more about where these metals come from.

Students read *Ore deposits are a source of valuable metals and minerals.* Complete the attached quiz. Share out major takeaways with the word, phrase, sentence method.

Day 2

We started to talk about critical metals yesterday. But what is metal, really? Access the *Periodic Table*, click on the “metal” classification, and unpack the definition there: What does it mean to be malleable? Conductive of heat? Conductive of electricity? Why are such materials desirable to modern humans? Discuss as a class.

Watch *Chemistry: What is a Metal?* and take guided notes in science notebooks. Stop the video as each property is discussed. Make sure that students have a separate heading for each metallic property, a definition in their own words, and a layman’s explanation for how a metal exemplifies that property.

Explore with some different metals. Compare their properties with one another, and add a corresponding data chart (luster, malleability, ductility, conduction of heat, conduction of electricity) to science notebooks. Conductivity of heat and electricity will be performed by the teacher and observed by students. The others can be performed within groups.

Day 3

Yesterday’s work was a segue into some more specific forays into what we call critical metals. But before we set up our driving question board, let’s figure out what critical metals actually are. Read *U.S.-China trade: What are rare-earth metals and what's the dispute?* and complete the writing prompt. Small groups will each be assigned a quiz question to answer together and then share with the whole group.

Where do we find these elements on the periodic table? And what does it have to do with nature? Watch *Rare Earth Elements.* Toxic acid sounds like a terrible by-product. So does relying on other countries, who may not share our values. And are our values correct? Who decides? And what if a natural disaster or political dispute disrupts the supply chain? How do we cast a wider net for these materials? And there's more, of course. So now that we have all of this to think about, which questions do we have about rare earth elements, some of which are critical metals? Let's put them on the Driving Question Board.

We are mining a critical metal in the USA. Watch *The 'white gold rush': Inside a lithium mine, where stores of recyclable energy lie.* Pause occasionally for note-taking, specifically when environmental impacts are addressed. What are the effects of this mining? How might the source (national news) affect the credibility of this information? How do we know? Is it better for us to mine here in America?

Day 4 (but this may take longer)

Some of you might have wondered where your energy is coming from right now. We will be educating each other on that very subject today. Some of you will read *Drilling down into petroleum's impact on life on Earth.* Some of you will read *Coal is about to be toppled as the nation's leading power source, EIA says.* Some of you will watch/read *What is Nuclear Energy?* And some of you will read *Types of renewable energy.* You might have to look up additional information. Use the *Step-by-step guide and research rescue: Evaluating Credibility* to help you decide which sources to use. Each group will be responsible for creating two teaching slides and presenting them to the rest of the class. You'll have a template to use, and you must answer the following questions in your own words in your presentation:

- What is/are the name(s) of the energy?
- Where do we get it from?
- How do we get it?
- How/where do we store it?
- Why is it important to us as human beings?
- How does it impact other forms of life?

Of course, exceeding expectations means including relevant visuals and engaging your classmates.

You'll have the first forty minutes of class to prepare, and the twenty to present. Happy evidence hunting!

Day 5

Yesterday, you all did some wonderful presentations about some different types of energy, and how they affect the world. Let's make sure we're all on the same page about what that looks like. Set up a Notice/Wonder chart in your science notebooks. You're going to use it with each resource we think about today. Watch *Before-and-after photos show dramatic decline in air pollution around the world during coronavirus lockdown.* Look at *Satellite images show air pollution returning to pre-pandemic levels as restrictions loosen.* Watch *CO2 in the Ice Core Record.* Read *Renewable energy could power the world by 2050. Here's what that future might look like.* Read *As US aims to boost clean energy supply chain, critical minerals gap largely human-caused, analysts say.*

Share your noticings and wonderings with the class. Then, in your groups, create concept maps to show and explain the connections between climate change and energy usage in the past and future.

Day 6

There is a global consensus that we need to switch to battery power. But are we ready? What bothers you about batteries right now? Have you thought about it? We are going to watch a non-English-language video of a scientific investigation. Begin a Notice/Wonder chart in science notebooks. Prompt: Identify what is being investigated, and what the narrator did to ensure a fair test. Write down anything else that you noticed, too. Watch *Apple iPhone 12 Vs Apple iPhone 11 Battery Drain Test (2020 Vs 2019).* Stop at 2:20. What do you wonder? After students finish their own chart, share aloud. Anticipated wonderings include “Why did one phone drain faster than the other? What makes a battery work?” Explain to students that batteries are both simple and complex. And nowadays, as you have already started to understand, they are crucial. Draw a line under your chart, and continue to add to it with the next two resources. Watch *How Batteries Work- Adam Jacobson.* Read *Electric Cars and Batteries: How Will the World Produce Enough?* Does this help to answer any of your wonderings? Add your own model of a working battery to your “notice” section.

It’s time to apply what you know. Post the UN’s *17 Goals*, and discuss them in small groups. Are they better as absolutes or a generalized direction to aim in for our future? Why? Share back to the whole group.

Write **mine more critical metals - recycle the critical metals - continue to use fossil fuels - use nuclear energy- use less energy** on the board. These are some ideas that have been brought up over the last two weeks. So far, knowing what you know, what do you think we should do as a future energy solution, and why? Discuss this as a class.

Revisit the Driving Question Board and see what has been answered, and which questions we still have.

Day 7-10

It is now time to do some self-guided learning. Answer these questions about a critical metal (you can choose one from the green box) in a slideshow, essay, or creative format. You must present your work and cite all sources used. Remember to use the *Step-by-step guide and research rescue: Evaluating Credibility* to make sure that your work is reliable. Refer to the rubric to exceed expectations.

1. What is the atomic structure of this critical metal?

2. How is this metal extracted from the environment?

3. What is its supply chain?

3. What are this metal’s physical and chemical properties (including phase change temperatures)?

4. How is the element used to store potential energy?

5. How is the element used by humans? Which products is it found in? How is it disposed of?

6. What are the impacts to society of extracting and using this element? What are the impacts to the environment of extracting and using this element?

Materials Needed

Smartboard, chromebooks, science notebooks, pencils, aluminum wire, iron wire, copper wire, flashlight, hammer, infrared thermometer, ohmmeter, and any preferred art materials (for days 7-10).

Resources

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Classroom Resources

(Make sure some copies of these resources are available offline.)

DR Congo Miners Work in Treacherous Conditions. Al Jazeera. Retrieved November 28, 2021, from https://www.youtube.com/watch?v=1TL7hTx5z0k

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What is Nuclear Energy? National Geographic Society. Retrieved November 28, 2021, from https://www.nationalgeographic.org/video/what-nuclear-energy/

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Wood, J. (2020, 28 February). Renewable energy could power the world by 2050. Here's what that future might look like. *World Economic Forum*. https://www.weforum.org/agenda/2020/02/renewable-energy-future-carbon-emissions/

Penrod, E. (2021, June 17). As US aims to boost clean energy supply chain, critical minerals gap largely human-caused, analysts say. *Utility Dive.* https://www.utilitydive.com/news/as-us-aims-to-boost-clean-energy-supply-chain-critical-minerals-gap-largel/599839/

Apple iPhone 12 Vs Apple iPhone 11 Battery Drain Test (2020 Vs 2019). MASTER mini TECH. Retrieved November 24, 2021, from https://www.youtube.com/watch?v=5g4_KTNUch8

How Batteries Work- Adam Jacobson. TEDEd. Retrieved November 28, 2021, from https://www.youtube.com/watch?v=9OVtk6G2TnQ

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Appendix

PA Eligible Content (Retrieved October 14, 2021 from 21-22 Grade 7 Science YAG):

- S8.C.2.1.1 Distinguish among forms of energy (e.g., electrical, mechanical, chemical, light, sound, nuclear) and sources of energy (i.e., renewable and nonrenewable energy)
- S8.C.2.1.3 Describe how one form of energy (e.g., electrical, mechanical, chemical, light, sound, nuclear) can be converted into a different form of energy.
- S8.C.2.2.2 Compare the time span of renewability for fossil fuels and the time span of renewability for alternative fuels.
- S8.C.2.2.3 Describe the waste (i.e., kind and quantity) derived from the use of renewable and nonrenewable resources and their potential impact on the environment.

Linked Science Standards (Retrieved October 14, 2021 from NGSS Standards):

- MS-PS1-1 Matter and its Interactions
- Develop models to describe the atomic composition of simple molecules and extended structures.
- MS-PS1-4 Matter and its Interactions
- Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed.
- MS-PS3-2 Energy
- Develop a model to describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system.
- MS-ESS3-4 Earth and Human Activity
- Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems.

Linked English Language Arts Standards (Retrieved October 17, 2021 from PDESAS):

- **CC.1.5.7.G** Demonstrate command of the conventions of standard English when speaking based on grade 7 level and content.
- **CC.1.4.7.C** Develop and analyze the topic with relevant facts, definitions, concrete details, quotations, or other information and examples; include graphics and multimedia when useful to aiding comprehension.

Standards- Based Category	Exceeds Expectations (4)	Meets Expectations (3)	Approaches Expectations (2)	Does Not Meet Expectations (1)
(Design) MS-PS-1-1 Develop models to describe the atomic composition of simple molecules and extended structures.	Model of critical metal, as well of models of extraction processes and supply chains, are exceptionally organized in terms of design, layout, and neatness	Model of critical metal, as well of models of extraction processes and supply chains, are organized in terms of design, layout, and neatness	Model of critical metal, as well of models of extraction processes and supply chains, are attempted, though they may be difficult to comprehend	Model of critical metal, as well of models of extraction processes and supply chains, are incomplete
(Knowledge) **MS-PS-1-4** Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed. **MS-PS-3-2** Develop a model to describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system.	Project includes all phase change temperatures of the critical element as well as additional information (physical and chemical properties) Project explains in detail how interactions of objects affect how potential energy is stored in the critical element	Project includes all phase change temperatures of the critical element Project explains how interactions of objects affect how potential energy is stored in the critical element	Project includes all phase change temperatures of the critical element Project discusses how potential energy is stored in the critical element	Project is missing some phase change information Project includes little to no discussion of stored energy with regards to the critical element

(Application) **MS-ESS-3-4** Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems.	Project explains all extraction processes and three of the element's uses by humans. Disposal methods are evaluated. Student clearly evaluates how their element's consumption impacts Earth's systems.	Project explains some extraction processes and three of the element's uses by humans. Disposal methods are explained. Student clearly explains how their element's consumption impacts Earth's systems.	Project mentions some extraction processes and less than 3 of the element's uses by humans. Disposal methods are defined. Student somewhat explains how their element's consumption impacts Earth's systems.	Project includes little to none of the extraction processes, no disposal methods, and less than 2 of the element's uses by humans. Student states that their element's consumption impacts Earth's systems.
(Process) CC.1.4.7.C Develop and analyze the topic with relevant facts, definitions, concrete details, quotations, or other information and examples; include graphics and multimedia when useful to aiding comprehension.	3 or more sources were cited, all other work deepens concepts in the student's own words.	3 sources were cited, all other work is clear and in the student's own words.	2 sources were cited, all other work is in the student's own words.	1 or fewer sources were cited, all other work is in the student's own words.
(Presentation) CC.1.5.7.G Demonstrate command of the conventions of standard English when speaking based on grade 7 level and content.	Speaker maintained eye contact and spoke with a loud, clear, and enthusiastic voice. Conclusion is profound.	Speaker maintained eye contact and spoke with a loud, clear voice. Conclusion supports the information.	Speaker mostly maintained eye contact and spoke with a clear voice. Conclusion repeats information.	Speaker barely maintained eye contact and spoke with a low, mumbled voice. Conclusion is inconclusive.

This rubric outlines what students are expected to accomplish in their independent research. Small-group and whole-group methods will use a total-access slideshow to guide students through instruction. They may use the Cornell method of note-taking, and will be encouraged to use concept mapping, as well as other informational organizational methods. They will only be formally assessed on meeting these standards in their summative project, though informal formative assessments will occur in the earlier stages of this unit.