What causes the Northern Lights?

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Introduction

St. Georges Technical High School is located in Middletown, Delaware, and is one of four vocational high schools comprising New Castle County Vocational Technical School District. The school serves approximately 1,100 students, while the district serves approximately 4,600.[1] Although St. Georges Technical High School (St. Georges) is located in a relatively rural community, it serves a variety of students from across the county. This means it pulls students from urban, suburban, and rural areas. Students are eligible to apply to St. Georges if they reside anywhere in New Castle County, Delaware. St. Georges receives more applications for incoming freshmen than they are able to accept, so a random lottery selects incoming freshmen. Unlike many vocational schools, St. Georges enrolls all students full-time, meaning students are in the building for the entire day as opposed to attending their home school for their traditional subject area courses before transferring to the vocational setting for a portion of the school day. Students receive all necessary academic and vocational courses in one location. As for demographics, during the 2017-2018 school year the student population at St. Georges was 49.1% white, 33.7% African American, 12.3% Hispanic/Latino, 3.0% multi-racial, 1.6% Asian, 0.2% American Indian, and 0.2% Hawaiian.[2] Twelve percent of students at St. Georges are considered special education students, 15.2% are low income, and 0.6% are English Language Learners.[3]

There are sixteen vocational career areas at St. Georges, including Information Technology, Web and Print Technology, Carpentry, Electrical Trades, Heating, Ventilation, and AC, Plumbing, Athletic Healthcare, Emergency Medical Services, Health Information Technology, Medical Assisting, Nursing Technology, Culinary Arts, Early Childhood Education, Biotechnology, Technical Drafting, and Auto Technology. St. Georges is in a unique position in that it truly has a task of making students both college and career ready. As a vocational high school, it is important for students to be trained and certified for their chosen career area, but also that they are prepared to become qualified and competitive college applicants if they so choose. Many students in the construction trades obtain a job directly after high school, while many students in the science career areas head off to college. As an academic teacher at St. Georges, it is my job to ensure I prepare each student for their respective path. With that said, it is worth noting St. Georges is a fully inclusive school and there are no honors or AP science classes, so all courses include students from a variety of academic levels. This, in combination with the fact that the St. Georges students are coming from different schools with varying curricula, presents the difficult task of ensuring all students have sufficient background knowledge in order to become successful as they learn new content in my course. As a result, all lessons must be developed so that students of a wide range of ability will be successful, but also challenged.

Rationale

This is my second year participating in the Delaware Teachers Institute (DTI). Through DTI, I hope to first and foremost increase my content knowledge of light and the electromagnetic spectrum. My seminar, *What is Light and How Can We Use It?* has the opportunity to provide me with a deeper understanding of topics covered in both my chemistry and physical science courses. I hope this greater understanding of the content will allow me to reach my students on a deeper level and to develop more meaningful and interesting lessons, which can then be passed on to other teachers throughout the state and country via DTI.

This unit is intended for use in my chemistry course at St. Georges. Major topics of the course include gas laws, phases of matter, atomic structure, electrons, bonding and naming of chemical compounds, chemical reactions, and stoichiometry. With the development of my unit, I plan to focus on NGSS standard HS-PS1-1: Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms. This standard is covered in the ninth-grade physical science course, but we delve deeper into the content for the eleventh and twelfth grade chemistry course. Although this standard is already taught in my course, I hope the information I learn through DTI this year will allow me to create a revised lesson that incorporates components of technology, student discovery and collaboration. This unit will be somewhat of a "mini unit" under the broader scope of the *Atomic Structure and Electrons* unit of the St. Georges chemistry course. While completing the *Atomic Structure and Electrons* unit, students learn a mix of topics including isotope abundance, nuclear reactions, half-life, electron configuration, and periodic trends. Within the electrons unit there is a small subsection relating to the cause of light emission from atoms. My DTI unit will focus on this subsection.

St. Georges is currently implementing initiatives in the areas of technology and literacy. Each student at the school receives a Chromebook to use while they are in class and at home, so I do have the ability to incorporate blended learning activities into my lessons. Over the past two years, all science teachers at St. Georges have been working on incorporating CER (Claim, Evidence, Reasoning) writing strategies into their lessons. CERs are an important component of the Next Generation Science Standards. I plan to develop lessons that incorporate both technology and writing strategies in a cohesive manner. The activities prepared for students will be components of a true blended learning experience for the students, with which they will be asked to complete assignments with and without the use of technology.

Student Learning Objectives

The first objective of this unit is for students to be able to describe, in simple terms, the connection between light and energy. A basic understanding of light is essential to being able to explain how it can be emitted from an atom as a result of the movement of electrons between energy levels. The second objective of this lesson is for students to understand that energy, in the form of photons, is what causes electrons to move from one energy level to another within an atom. This leads directly into the third objective of the unit, which is for students to be able to explain that light is emitted from an atom when an electron moves from the excited state back down to the ground state.

Once students have mastered each of these three objectives, they should be able to apply their new knowledge and connect this information to the northern lights. This may require a small bit of additional research on their end (included in the developed unit activities), but the bulk of their understanding will come from the information they learn as they complete the preceding unit activities.

Key Learning

Chemistry is an upper-level elective science course at St. Georges, meaning by the time students reach my course all required high school NGSS standards will have already been covered to an appropriate depth. With that said, the information from this unit does not directly relate to one standard, but builds upon HS-PS1-1: Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms.

According to the Next Generation Science Standards[4], there are a number of Disciplinary Core Ideas (DCIs) NGSS standard HS-PS1-1. Upon completion of this unit, students will be able to describe that each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons. They will also understand that the periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns They will also be able to recognize that the repeating patterns of this table reflect patterns of outer electron states. Finally, students will understand that the structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms.

Essential Questions

Essential questions are a component of the Learning Focused Instructional Framework (LFS). LFS is an instructional model common to schools across the state of Delaware. It provides students with a type of concept map developed to assist in guiding the lessons for a given unit. Each unit has one guiding Essential Question, while each lesson has a more focused essential question.

- Unit Essential Question: What causes the Northern Lights?
    - Lesson Essential Question #1: What is light?
    - Lesson Essential Question #2: What causes electrons to move within the energy levels of their atoms?
    - Lesson Essential Question #3: How does the movement of electrons emit light from an atom?

Unit Content Objectives

Student Prior Knowledge

Due to the abstract nature of atomic emission spectrum, it is a topic that can be difficult for students to understand. Students must have thorough background knowledge in a variety of areas in order to be able to understand how it is possible for light to be emitted from an atom. At this point in the course, many of the chemistry topics from the St. Georges ninth grade physical science class learned in ninth grade would have been reviewed. Since chemistry is strictly an eleventh and twelfth grade course it is essential that these topics be briefly reviewed, as it has been over a year since students have seen this information. Essential background information for students to become successful with the content of this unit is as follows:

Atomic Structure

Knowledge regarding atomic structure is an essential component in order to be able to the process electrons go through in order for an atom to emit light. During the atomic structure unit, students learn about the three major components of atoms, protons, neutrons, and electrons. Students learn the respective charges of these three subatomic particles (protons = positive, neutrons = neutral, electrons = negative) as well as their locations within the atom (protons and neutrons in the nucleus, while electrons orbit the nucleus in the electron cloud). We discuss the concept of valence electrons, and students learn how to determine the number of valence electrons for groups 1A-8A based on their location on the periodic table.

Electromagnetic Radiation

In order to fully comprehend information given to students during the unit, students must understand the electromagnetic (EM) spectrum, an essential component of atomic absorption and emission. Although students should be familiar with the EM spectrum leaving middle school as well as ninth grade science, the concepts must still be reviewed. Students must be aware that the red end of the visible spectrum has a lower frequency and longer wavelength than blue or violet light at the opposite end of the spectrum. Wave properties such as wavelength and frequency may also need to be reviewed at this point, depending on student prior knowledge regarding waves.

Key Unit Content

Light

The electromagnetic spectrum describes all electromagnetic (EM) waves of any wavelength. All electromagnetic waves travel at the speed of light (300,000 kilometers per second) in a vacuum or in air.[5] Students should understand that EM waves travel through materials at a speed less than speed of light and that the change in speed when light passes through a curved interface (e.g. between glass and air) causes the light to bend. This is what leads to focusing elements like the lenses in glasses or telescopes. Because all EM waves have the same speed when propagating in a vacuum, the product of the wavelength and the frequency is a constant for any EM wave. All of these forms of EM radiation transfer energy in the form of photons from one location to another. The possible wavelengths of EM waves range from larger than a football field to smaller than an atom, and thus the way a wave interacts with matter depends a great deal on its wavelength. The range of wavelengths in the EM spectrum are broken into seven categories that describe these differences qualitatively: radio waves (very long wavelengths), microwaves, infrared light, visible light, ultraviolet light, x-rays, and gamma rays (very short wavelengths).[6] The light we see on a daily basis comes from the visible portion of the electromagnetic spectrum. An individual photon of shorter wavelength (higher frequency) has more energy than an individual photon of a longer wavelength. In other words, radio frequency waves carry the least amount of energy per photon because they have the longest wavelengths and lowest frequencies, while gamma rays carry the most energy per photon because they have the shortest wavelengths and highest frequencies. However, the amount of energy carried in a beam of electromagnetic radiation depends on both the energy per photon and the number of photons emitted per second. The number of photons emitted per second is just a way of quantifying the brightness of the light source. For example, one could have a bright red laser or dull blue laser. A blue photon carries more energy than a red photon, but if the red laser is releasing more photons per second in its beam, the red beam can be transferring more energy than the blue beam.

The focus of the lessons within the unit will remain on visible light, but it is important to note that other forms of electromagnetic energy can be released from atoms as well. If photons containing more or less energy than the range of visible light are emitted, humans will not able to detect them with the naked eye. They would be observable, however, with, for example, cameras that are sensitive to ultraviolet or infrared light.

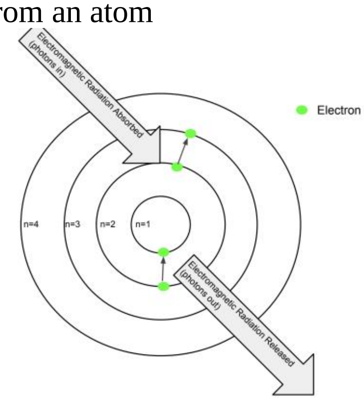
Atomic Emission

An extremely common high school chemistry lab involves what is called the flame test. When students conduct the flame test, they place metal ions in a Bunsen burner flame and cause the flame to change color. This is a perfect activity for explaining atomic emission spectra. When ions of dissolved salts are placed in a flame, different colors of light are emitted. These colors are a result of the movement of the electrons within the atom. As previously mentioned, for students to understand the process occurring here they must have a thorough understanding of atomic structure.

When metal ions are placed in a flame or similar source of energy, electrons within the atom are able to absorb photons from that flame. This excess energy "excites" the electrons and causes the electrons to move from the ground state to an excited state. The ground state of an atom exists when electrons are orbiting the nucleus of the atom within their assigned energy level. After electrons absorb energy, they move up one or more energy levels and are considered to be in their excited state. These electrons are very unstable when in this excited state, and quickly move back down to their original assigned energy level. In order for this to happen, however, the energy that was originally absorbed by the incoming photons must then be released. This release of energy is often given off in the form of visible light of a specific wavelength that students are able to see. Figure 1 below diagrams the absorption and release of photons as an electron move to excited state from their ground state and back down again.

During this process, if the atom absorbs a photon of a certain wavelength, such as the wavelength corresponding to that of blue light, a blue photon will be released when the electron moves back to its ground state and the number of blue photons would be the same. If this is the case, students may wonder why a color change would result. The answer stems from the fact that EM radiation of wavelengths invisible to the naked eye may be absorbed, moving the electron to much higher energy levels. The electron relaxes in multiple steps by emitting multiple photons, some visible and some invisible to the naked eye. The characteristic colors we see is determined by these mid-points that electrons relax to before emitting the "last" photon of a characteristic color.

Figure 1: Release of photons from an atom



Different elements require different amounts of energy to be absorbed in order to move electrons within energy levels. Because of this, each element releases a unique wavelength of electromagnetic energy when placed in a flame. This in turn results in a unique color in the flame. Table 1 details common elements along with the color produced. With this information, students are able to identify elements present based on the colors they see within the flame.

Table 1: Flame colors of common elements[7]

Element	**Color Produced**
Lithium	Red
Sodium	Strong Orange
Potassium	Lilac
Rubidium	Red-Violet
Cesium	Blue-Violet
Calcium	Orange-Red
Strontium	Red
Barium	Pale Green
Copper	Blue-Green
Lead	Gray-White

Gas Discharge Lamps

Gas discharge lamps may be used as another method to show students that elements contain their own visible light "footprint." These lamps work using the same principles as the ions in flames, and depending on the specific gas within the discharge tube, different colors can be seen. Table 2 provides examples of possible gases that can be used along with the color each produces.

Table 2: Gas colors[8]

Gas	**Color Produced**
Hydrogen	Blue-Violet
Helium	Pink Orange
Neon	Red
Argon	Violet
Krypton	Lavender
Xenon	Blue
Mercury Vapor	Blue-Violet
Oxygen	Blue-Violet
Water Vapor	Pink

Teachers may choose to provide students with a pair of diffraction glasses to look through while viewing the gas discharge tubes. Diffraction glasses are outlined in the following section.

Diffraction Glasses

Diffraction glasses may be a useful tool to help students understand the major concepts of the unit. They use a method known as diffraction grating, which works similar to a prism in that it causes white light to be separated into its constituent color components. Glasses with diffraction grating have thousands of tiny slits within them. When light passes through these tiny slits, interference between the beams coming through each slit causes the light to bend by an angle that depends on the wavelength. For a given width and periodicity of the slits, red light bends, or diffracts, more than blue light because of its longer wavelength.[9] When looking through diffraction glasses at white light, which contains a combination of all colors, a rainbow can be seen. Gas discharge lamps contain gases of very specific elements, which only emit a small number of wavelengths of light. With diffraction glasses, one would see these specific wavelengths as distinct lines of individual colors. Each element has its own unique color "fingerprint," and can be identified based on the wavelength(s) being emitted.

The Northern Lights

The Earth is made up of four layers: the crust, mantle, outer core, and inner core. The temperature and pressure increase with increasing proximity to the center of the Earth. Within these layers are magnetic metals heated to such high temperatures that they are in the liquid state, resulting in magnetic field lines that travel from Earth's northern pole to its southern pole.[10] These magnetic field lines create a protective layer called the magnetosphere, which protects the Earth from energetic electrically charged particles emitted from the sun. Billions of charged particles may be released from the sun during a solar storm, and sent barreling towards the sun at millions of miles per hour.[11]

As these charged particles enter the magnetosphere, they collide with atoms such as oxygen or nitrogen in our atmosphere.[12] As they collide, the electrons within the atoms move from the ground state to the exited state and back, resulting in visible light being emitted from the atoms (what we see as the northern lights). Depending on the altitude of this interaction, different colors are emitted. Blue-violet auroras and red streaks of light appear at altitudes below 60 miles; bright green lights are strongest between 60-150 miles; and ruby reds can be found at altitudes beyond 150 miles.[13]

Teaching Strategies

Science teachers at St. Georges, along with their colleagues from schools across New Castle County Vocational Technical School District, are in the process of redesigning the curricula of their science classes to align with NGSS teaching methodology. The NGSS platform of instruction incorporates an inquiry-based lesson format, requiring teachers to assist students in discovering the information for themselves as opposed to the traditional direct instruction lecture. In addition, St. Georges is currently in their fourth year of a school-wide literacy initiative. The ultimate goal of this literacy initiative is to improve upon students' reading, writing, listening, and speaking skills. My unit will incorporate inquiry-based activities as well as those requiring various literacy skills.

The Next Generation Science Standards include a component titled Science and Engineering Practices, which outlines a list of skills common among scientists and engineers, that students should become familiar with in order to be successful in careers after high school. There are eight total Science and Engineering practices that can be found on the NGSS website, but this unit is built upon one in particular: Obtaining, Evaluating and Communicating Information. As students conduct self-guided research, they must be able to find the information on their own and determine what is essential based on the research requirements before ultimately sharing their information with the rest of the class.

The Next Generation Science Standards also rely on inquiry-based teaching methods to be incorporated in the classroom. Throughout this unit, students will be guiding their own learning by coming up with their own questions to investigate, and by learning through answering these questions. Inquiry-based lessons and activities provide students with a deeper understanding of the material because it requires the student to explore and direct their own learning. This leads to a more meaningful connection to the topic, as well as a better chance for remembering the information, as the student often connects the information to a real-world scenario.

St. Georges, along with many other schools across the state of Delaware, utilizes a learning management platform called Schoology. Schoology is an educational website allowing teachers and students to interact with one another in many ways that were once only possibly in person or on paper. Schoology provides countless opportunities for teachers to upload documents, assignments, tests and quizzes, links to outside websites, discussion boards, and other items in one central location for students to find. It assists the teacher in developing a truly blended learning experience for the student. Schoology has proven itself to be a valuable resource for many of the lessons I have developed for my course, and I plan on incorporating the use of this valuable website into this unit as well.

Another framework utilized across the state of Delaware is the Learning Focused Schools (LFS) model. LFS has been common among Delaware schools for a number of years, so most students are familiar with the setup. Student Learning Maps (SLMs) are an essential component of the LFS framework. SLMs are based upon a certain Unit Essential Question, which is based on the state or national standard(s) to be covered over the course of the unit. The unit is then broken down into approximately 3-4 subcategories, referred to as concepts. Each concept has its own Lesson Essential Question (LEQ) with vocabulary that follows. The goal of the SLM is to provide students with somewhat of an outline to help organize the information they are receiving. SLMs are frequently referred to by students and teachers as the class makes their way through the unit. This unit will have its own SLM to allow students an opportunity to organize the information they are receiving throughout the unit.

Classroom Activities

Activity 1: Phenomenon and Initial Student Model

Students will be shown a short video clip of the Northern Lights, or Aurora Borealis, occurring in nature. A variety of videos are available to select from on www.YouTube.com. Students will be placed in to groups, preferably pairs or groups of three, to discuss their opinions regarding why they believe this occurs and how they believe it relates to chemistry class. Students will be asked to make the following chart on a poster and fill in as much information as possible.

Observations	Questions we have	What we know

The format of this table is meant to align with the NGSS Driving Question Board model[14]. Providing students with a phenomenon and giving them time to determine why they believe the phenomena occurs allows for greater interest and buy-in on the student end. This also provides the teacher with an opportunity to gauge student prior knowledge before the unit begins. According to the Next Generation Science Standards, Driving Question Boards are meant to act as a guide for students and teachers to repeatedly refer back to and reference as they work their way through the unit. The goal is for students to come together and “pave their own way” through the learning and discovery process.

The second task for students to complete during this activity is a model. Students will use either the reverse side of their chart paper or a separate piece of poster paper to draw a model of what they believe is occurring to cause the Northern Lights. They will be asked to include drawings as well as labels and a brief explanation of what they have included in their model to ensure they are clear with what they believe is their understanding of the process of the Northern Lights. The goal of developing a model this early in the unit is to gauge student knowledge. This gives the teacher a clear understanding of any misconceptions the students may have and what they have yet to learn.

After all groups have completed their chart and model, the class will come together to discuss. This can be conducted via a whole class discussion, or in smaller groups via an activity similar to a gallery walk. After sharing ideas, a class consensus should be made to incorporate the collective ideas of all students in the class. Students will refer back to this model and revise periodically as they work their way through the unit.

Activity 2: Flame Lab, Gas Discharge Tubes, and Direct Instruction

The second activity in this unit involves a common flame lab, as conducted in many general high school chemistry courses. During the flame lab, aqueous solutions of salts are placed in a flame to produce a flame of a specific color. A variety of salts can be used for this lab, but some include sodium chloride, copper (II) chloride, potassium chloride, calcium chloride, strontium chloride, barium chloride, and lithium chloride. Students will work in groups of two to four to analyze the color produced, and take notes on a student sheet. It is essential that the teacher model and practice appropriate Bunsen burner technique as well as safety procedures before the lab takes place.

Once students finish with the flame lab, gas discharge tubes will be utilized to show another example of colors being produced from certain elements. Examples of gases that may be used include hydrogen, helium, neon, argon, and oxygen. Students will be asked to make observations and take note of the color they see with each element before viewing the discharge tubes with diffraction glasses. Students will be asked to record their observations on paper, and compare any similarities and differences to what they saw with the flame lab. They will also be asked to discuss what they believe the purpose of the diffraction glasses is with their group.

The teacher will next lead a class discussion regarding the relationship between movement of electrons and colors produced. Students will take notes. The teacher should discuss the movement of electrons within energy levels, and how different colors end up being produced. The teacher can also relate the discussion to the gas discharge tubes and diffraction glasses.

Upon completion of the direct instruction portion of the lesson, students will be asked to respond to the following writing prompt: In your own words, explain the process that occurs with electrons when dissolved salts are inserted into a flame. A full description should use the following terms: electron, excited state, photon, ground state, energy level, color, wavelength, energy.

Activity 3: Connection to the Real World

For the final portion of the unit, students will use what they have learned in addition to any necessary research to link the movement of electrons within energy shells of atoms to the Northern Lights. They will be asked to answer the original driving question, "What Causes the Northern Lights?" In order to fully answer this question, students will likely need to spend some time conducting additional research. They will be given time to work in pairs to answer the question. Pairs of students will be asked to develop a visual representation to describe the steps that occur and during this process. During this activity, students will be taking time to review their original models from the beginning of the unit. They will discuss with their partner any misconceptions they had at the beginning of the unit, and correct those misconceptions in their visual representation. Students should be able to describe that high energy photons from the sun excite electrons within has molecules in the air within Earth's atmosphere. The electrons quickly move back to their ground state, releasing photons that we see as the characteristic colors of the Northern Lights. They should also be able to link this process to what they saw in the flame lab and gas discharge demonstration.

Summary of Activities

All student activities are closely aligned with components of the Next Generation Science Standards as well as discovery-based learning techniques. The activities also follow additional Next Generation concepts by having students develop models and conduct inquiry-based learning activities. Activity three requires students to conduct an investigation in order to obtain information answering the Lesson Essential Questions. The activities also align with current initiatives of St. Georges, including increasing literacy across content areas as well as incorporating the use of technology and blended learning in the classroom. Throughout this unit, students will be required to filter though information in both textbook and web format. They will need to thoroughly comprehend the information they are reading in enough detail to take the information and develop a detailed visual representation of the information they have learned. As for blended learning, this unit incorporates tasks that utilize traditional instruction techniques as well as technology. The student research, and visual representation may utilize technology, contributing to the use of blended learning in the classroom.

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Great tool for learning how to incorporate NGSS in your classroom.

Appendix A

Standards

According to the Next Generation Science Standards[15], there are a number of Disciplinary Core Ideas (DCIs) and Crosscutting Concepts (CCCs) that align with NGSS standard HS-PS1-1. After completing this unit, students will describe that:

DCIs
- Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons. (HS-PS1-1)
- The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states. (HS-PS1-1)
- The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. (HS-PS1-3),(secondary to HS-PS2-6)

CCCs
- Patterns
  - Different patterns may be observed at each of the scales at which a system aphenomena. (HS-PS1-1),(HS-PS1-3)

There are also a number of Common Core standards this standard addresses:
- ELA/Literacy –
  - RST.9-10.7 Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words. (HS-PS1-1)
  - RST.11-12.1 Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-PS1-3), (HS-PS2-6)
  - WHST.9-12.2 Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (HS-PS2-6)

    - WHST.9-12.7 Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. (HSPS1-3)
    - WHST.11-12.8 Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation. (HS-PS1-3)
    - WHST.9-12.9 Draw evidence from informational texts to support analysis, reflection, and research. (HS-PS1-3)
- Mathematics –
    - MP.4 Model with mathematics. (HS-PS1-8)
    - HSN-Q.A.1 Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays. (HS-PS1-3),(HS-PS1-8),(HS-PS2-6)
    - HSN-Q.A.2 Define appropriate quantities for the purpose of descriptive modeling. (HS-PS1-8),(HS-PS2-6)
    - HSN-Q.A.3 Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. (HS-PS1-3),(HS-PS1-8),(HS-PS2-6)

Notes

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