The Sun and Its Energy

Monica Cohen

Introduction

St. Georges Technical High School is one of four vocational-technical high schools in New Castle County, Delaware. The 1,119 students enrolled at St. Georges, represent a diverse community – urban Wilmington, suburban Newark, and rural Middletown. Students apply to St. Georges for a variety of reasons: to learn a family trade, learn in a safer school environment when compared with a feeder high school, or earn a certification to join the workforce instead of continuing to a post-secondary school. Approximately fifty percent of the graduating class directly joins the workforce, an apprenticeship, or trade school. The remaining fifty percent continue on to college/university, or a branch of the military.

The technical school environment offers students a unique high school experience. Each student earns a certificate or license in their field of study upon graduation. The trades offered to our students are as diverse as the students themselves; ranging from nursing to carpentry, web design to culinary, automotive technology to early childhood education, and a dozen other options. In the school year 2016—2017, out of 802 upperclassmen (sophomores, juniors, and seniors), 20% study a trade in the Public/Consumer Services cluster, 23% study a Construction trade, 35% study in the Health Career cluster, and 23% study in the Business and Technology cluster.

Although St. Georges is a technical trade school, it is considered a branch of the public-school system. Therefore, students have access to their career classes in addition to the state-mandated academic courses offered within St. Georges. I am one of the science instructors within the building; teaching Biology to sophomores and Integrated science (Earth and Space) to juniors. This unit has been developed for Integrated Science. Many of the students who take Integrated Science in their junior year, study the construction trades and do not intend to apply to a four-year institution post-high school. These students are more likely to join an apprenticeship, begin working in the field or attend a two-year institution to receive an associate's degree. This junior year course covers the topics of astronomy and climate science.

As a fully-inclusive school, students of all ability levels, both regular education and special education students, are placed in the same class and therefore it becomes important for the instructor to be able to differentiate each lesson. Following the blended learning educational model, this unit provides students with several choices in how they learn, express their knowledge, the pace at which they learn, and utilize technology to enhance their overall learning experience. Within the blended model, the teacher becomes a facilitator while the student becomes the gatherer and organizer of information. My role as a facilitator is to provide students with appropriate resources to extract information and scaffold the lesson. It is important that the teacher carefully identifies a limited set of videos, articles, and simulations to provide the students with a choice in gathering information.

The state of Delaware has adopted the Next Generation Science Standards (NGSS) and is currently implementing them into the high schools. Many standards traditionally taught in our eleventh-grade Integrated Science course have been redistributed to ninth and tenth-grade sciences. Therefore, the new standards for this course have significant differences compared to last year when I taught this course. With fewer standards to cover, this unit will be able to delve deeper into the composition of the Sun and the energy produced. This unit is designed to enhance and supplement current topics discussed in the course while creating an interactive curriculum.

Rationale

This solar energy unit is designed to integrate science concepts with the school-wide focus on literacy. The literacy initiative includes an emphasis on reading, writing, speaking, and listening in order to improve scores on the SAT, which is currently being used as the benchmark to measure proficiency in schools. All content areas, including the technical trades, are responsible for incorporating literacy strategies into lessons per administrative request. Examples include analysis in a writing assignment, a reading strategy, and speaking/listening strategy. Each component of the unit is designed to highlight an aspect of literacy to support the school's vision and ultimately support the increase in SAT literacy scores. The literacy standards are also addressed in the Common Core State Standards and will create a cross-curricular unit plan.

With the enormous shift in standards for Integrated Science, there is no precedent for units taught, activities for students, or assessments. A handful of units from the previous curriculum are relevant to a slight degree; one of which will be utilized as a starting point when developing this unit, although the depth of knowledge and extent of connection between related topics is unknown territory. The goal of this unit is to create a new curriculum for what will essentially be a new course. This unit will include engaging hands-on experiences to enhance student comprehension and create scaffolds as students' progress through the unit. In accordance with the school's literacy focus, students will be expected to gather notes in an organizer by reading text, listening to videos, having group discussions, completing laboratory assignments and related discussion questions, and completing at least one writing assessment with an associated rubric.

The unit on solar energy will be divided into four major sections. Students will study the composition of the sun – its chemical composition, anatomy, and important energy-generating process. A model of the Sun's layers is created by students and used in the writing portion of the unit; the second activity. Students display their understanding of the process of fusion and the basics of the equation $E = mc^2$. The equation demonstrates the correlation between mass and energy when mass moves at the speed of light (c). This knowledge allows students to excel in the comprehension of the transfer and transformation of energy through the sun. Understanding the chemical composition of our sun can be related to other stars in our galaxy. This discussion leads to the idea that stars are "living" objects based on their ability to complete fusion. As the third portion of the unit, students demonstrate that more massive stars continue the process of fusion for fewer years. The fourth component of the unit requires students to explore the technology utilizing electromagnetic waves. Human applications and Sun-Earth interactions of the different types of electromagnetic radiations are studied after understanding the relationship between energy, wavelength, and frequency. The last segment of the unit has students observe visible light through spectroscopy and apply its relevance to the anatomy of stars.

As a result of completing the curriculum unit, students have the ability to explain the generation of energy through the process of nuclear fusion and discuss how the electromagnetic radiation changes in energy level as energy passes through the layers of the sun. The observation of the sun's, and other stars', chemical composition through the use of spectroscopy is a skill demonstrated by students through a laboratory experiment using spectrometers. Students identify and explain how electromagnetic radiation can be harnessed and accessed by humans and incorporated into common technologies.

Content Objectives

With the completion of this unit, students will be able to:

- Create a model of the Sun's layers.
- Model the path energy, in the form of electromagnetic radiation, must travel from the sun's core to Earth.
- Explain the process of nuclear fusion as it relates to the equation $E = mc^2$.
- Explain how electromagnetic radiation is experienced by humans.
- Demonstrate how spectroscopy can be used to identify the chemical compositions of stars.
- Create a model describing the relationship between star mass and star lifespan.

Background Knowledge

Fusion

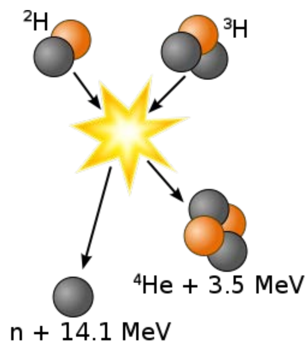

Figure 1. The fusion of deuterium and tritium to create helium, a neutron, and energy. Retrieved from https://commons.wikimedia.org/wiki/File:Deuterium-tritium_fusion.svg

Fusion is the step-wise process by which atoms are combined to create heavier nuclei while generating large amounts of energy. In order for fusion to occur, the temperatures and pressures must be great enough for repelling protons to be joined together by the strong nuclear force. This force acts like the glue that can overcome the repulsion of neighboring protons. One way that this repulsion is overcome is under high temperatures where particles move at very high speeds and when collisions occur, protons and neutrons come in close enough proximity before the electrical repulsion pushes them back apart.[1] The only place within the Sun that fusion can occur is the core. The inner quarter of the solar radius is where temperatures exceed 7 million Kelvin and can get up to 15 million degrees Kelvin.[2] Chemist Francis W. Aston invented the mass spectrograph which he used to show that the mass of one helium nucleus is slightly less massive, by 0.7% than the sum of masses from four hydrogen nuclei, which are each made of a single proton.[3] The remaining mass that is unaccounted for in the helium atom, is released as a neutron and energy as a result of the fusion process. It is known that both energy and matter cannot be created nor destroyed based on the laws of conservation, but according to Einstein's theory of special relativity, $E = mc^2$, matter can be converted into energy under the appropriate conditions and vice versa. The energy released is in the form of photons, which are tiny packets of light. Photons originally released from nuclear fusion exhibit extremely short wavelengths, high energy, and high frequency; progressing towards longer wavelengths and lower energetic radiations as it moves through the layers of the Sun. The relationship between these wave characteristics is further explained under the Electromagnetic Radiation section.

Solar Anatomy

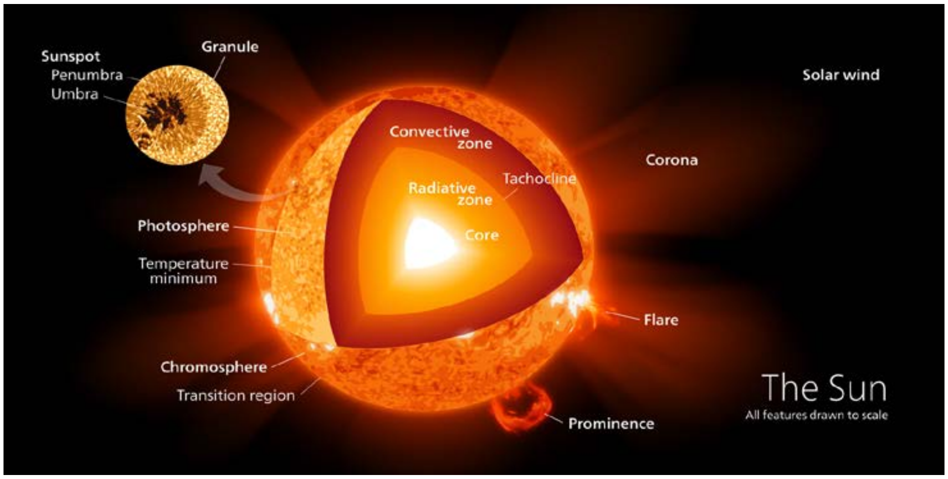

Figure 2. Artistic representation of the layers of the sun. By Kelvinsong via Wikimedia Commons; retrieved from https://upload.wikimedia.org/wikipedia/commons/d/d4/Sun_poster.svg

The anatomy of the Sun is similar to that of other stars. The core is the inner-most layer of the Sun where fusion is able to take place due to the extreme temperatures and pressures. The temperature in the core is proportional to a star's mass. For example, a star that is ten times as massive as the Sun is ten times hotter at its core.[4] Temperatures can reach fifteen million degrees Kelvin in the core of our Sun which is sufficient heat for nuclear fusion. The core only extends outward approximately one-quarter of the distance from the center to the sun's exterior, equating to 1.6% of the Sun's volume, yet containing about half of the Sun's mass.[5] The only way for this significant amount of mass to be contained in such a small volume would be if the density was extremely high, in part due to the inward pressure of gravity.

Beyond the core, photons move through the radiation zone, also referred to as the radiative zone. This layer of the Sun makes up seventy percent of its volume and it takes the longest amount of time for photons to pass through this region of the sun. The energy released from fusion in the core is in the form of gamma radiation. This radiation moves in a random walk, or zig zag pattern, through the radiation zone. It can take between 200,000 and 1 million years for a photon to enter and leave this part of the Sun. The reason for this long journey is the particle and wave nature that the photons exhibit. The energy is absorbed and re-emitted by the hydrogen atoms making up this solar layer and also some of these photons are bounced between atoms. Ideally, each re-emission of energy takes place further out in the radiation zone and therefore at lower temperatures. The lower temperatures would produce lower energy photons, however, in order to conserve energy, there have to be more photons, each at a lower energy level.[6] What began as a single gamma ray photon, is finally released as many lower energy photons.[7] This explains why high energy photons are not released from the Sun and make their way towards Earth.

After the long journey through the radiation zone, photons have a fluid path through the convection zone following the convection currents of the layer. This layer extends inward thirty percent of the solar radius.[8] Warmer plasma located near the edge of the radiation zone rises, or “bubbles up” toward the surface of the Sun while the relatively cooler plasma falls back towards the radiation zone. These convection currents are self-perpetuating with the variations in temperature between 1.5 million Kelvin at the surface of the radiative zone and 6000 Kelvin at the base of the photosphere.[9] The circular currents constantly move plasma and energy through the convection zone. Compared with the journey through the radiation zone, it only takes the plasma ten days to rise upwards before cooling and falling back down.[10] The eventual outcome of this rotation for the energy to be released to the next layer outward.

The surface of the Sun is known as the photosphere. This layer of the Sun is the visible surface, emitting visible light; yet can only be viewed using solar eclipse glasses that have the ability to block out 99% of the visible light emitted from the Sun due to the immense amount of visible radiation released. The photosphere has a dynamic appearance, with granules made of plasma, that appear to “bubble” to the surface at speeds tenths of a kilometer per second.[11] This granulation represents the end product of the convection zone, in which matter is churned by convection.[12] Individual granules only last approximately fifteen minutes before sinking back down and being replaced by another one on this dynamic solar surface.[13] Unique to this layer is the sunspots, which are darker, cooler regions on the solar surface. The darkest regions are the depressed umbra with a relatively cool temperature of 1500 Kelvin surrounded by warmer penumbra which slope back to the photosphere.[14] These sunspots change size, shape, and location as the Sun’s surface rotates around the sun’s interior. Sunspots are constantly changing and have individual lifetimes of days or weeks.[15] The observed motion of these sunspots led scientists to understand the differential rotation of the Sun’s surface. It has been calculated that the frequency of sunspots varies along an eleven-year cycle – from a solar minimum with few sunspots to a solar maximum with many sunspots, back to a solar minimum. After the eleven-year cycle, the magnetic field and polarities reverse, creating a twenty-two-year magnetic cycle.[16]

Beyond the surface, there are two layers to the Sun’s atmosphere – the chromosphere and corona. Both layers are much less dense than the photosphere and are therefore only visible during a total solar eclipse. Interestingly, moving from the core to more outward layers of the Sun, the temperatures decrease, yet the temperatures begin to increase as the energy moves outward beyond the photosphere. At the top of the photosphere, temperatures are approximately 4500 Kelvin and climb to more than 10,000 Kelvin in the chromosphere, and continue to climb to more than a million Kelvin in the corona.[17] The density of these atmospheric layers is lower in comparison to the photosphere and consequently, atoms move faster, creating higher temperatures.[18]

Electromagnetic Radiation

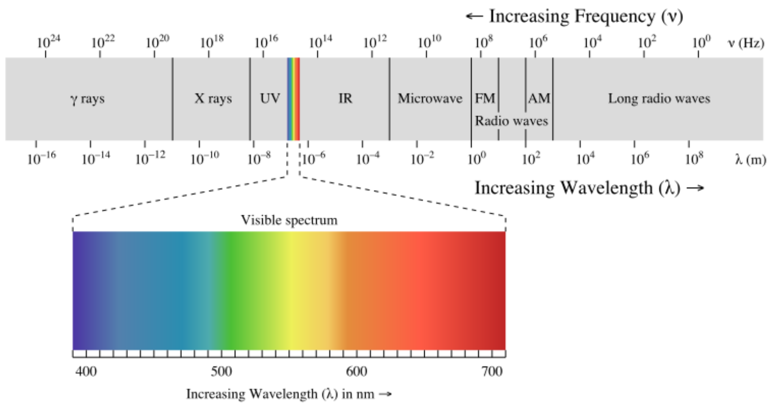

Figure 3. The electromagnetic spectrum in order from gamma (γ) radiation to radio waves. By Philip Ronan via Wikipedia Commons https://commons.wikimedia.org/wiki/File:EM_spectrum.svg

The different types of electromagnetic radiation are organized and identified based upon their unique set of wavelengths, energies, and frequencies. The relationship between wavelength and frequency is explained by the equation $c = \lambda\nu$; regardless of wavelength (λ) and frequency (ν), all waves travel at the speed of light (c).[19] Wavelength and frequency are inversely proportional to each other; the shorter the wavelength, the higher the frequency, and the longer the wavelength, the lower the frequency. The relationship between energy and wavelength is explained by Planck's equation: $E = h\nu$.[20] As photons, light energy, are absorbed and emitted by solar material, the change in energy (E) of photons that have been emitted is directly proportional to the frequency of photons (ν).[21] This equation can be used to describe the behavior of photons within the radiative zone, where photons are continuously absorbed and emitted by atoms.

These electromagnetic radiations include gamma, x-ray, ultraviolet, visible light, infrared, microwave, and radio waves in order of highest energy to lowest energy. Each of these energies impacts the Earth and human technology. Stars, including our Sun, emit all of these wavelengths, yet only visible, some ultraviolet, and radio waves ultimately reach the Earth's surface. Photons behave as both particles and waves on their journey from the core of the Sun to the Earth. As photons interact with the plasma within the layers of the Sun, they behave as particles – being absorbed and re-emitted, however, the same photons behave as waves when traveling through space.

Gamma rays are photons that exhibit the shortest wavelengths, highest energy, and highest frequency in relation to the other aspects of the electromagnetic spectrum. As stated above, energy and frequency are directly proportional to each other, while wavelengths are inversely proportional. This form of energy is produced in the core of stars through fusion. As photons attempt to escape from the Sun, they progressively decrease in energy along the way, increase the wavelengths, and decrease the frequency of each wave. As these characteristics change, the categorization of the wave changes from gamma to x-rays. This progression continues for upwards of a million years, or until the photons reach the corona. Much of the radiation that reaches the Earth's atmosphere from the Sun is in the form of ultraviolet radiation, 10-400 nanometers, and visible light waves, 400-700 nanometers. In order for astronomers to be able to study the radiation given off by other stars or other wavelengths from our Sun, telescopes must be sent above Earth's atmosphere because most of the ultraviolet and infrared radiation does not pass through to the earth's surface, and all of the cosmic x-rays and gamma rays are absorbed as well.[22] Radio waves are the only type of invisible radiation not absorbed by Earth's atmosphere.[23] Some of the visible light energy is decreased to infrared radiation as it moves through Earth's atmosphere. Although not all solar energy reaches Earth's surface, some of this energy from the solar wind interacts with Earth's atmosphere near the magnetic poles to create the Aurora Borealis and Aurora Australis; the northern and southern lights respectively.

Humans are able to apply all electromagnetic radiations to benefit our society through technological advances. We utilize radio waves to transmit radio, television, and GPS signals between Earth and satellites orbiting Earth, while microwaves allow humans to connect with each other through the operation of our cell phones. Infrared radiation, which is typically associated with heat, can be used in surveillance and muscle therapy but is also used in remote controls. Visible light is the wavelength band that humans are most familiar with because it is this band that the human eye is able to detect as colors. We use this to communicate with each other through signs, signals, and fiber optics. Ultraviolet radiation can be used in sterilization, such as in the class safety goggle cabinet. X-rays have extremely short wavelengths, ranging from 0.01 nanometers to 10 nanometers, and can penetrate a cell's nucleus and damage DNA. These waves are used sparingly and are associated with medical analyses – to detect broken bones and cavities in teeth. Gamma radiation is the most dangerous and can be used to destroy any type of cell – very beneficial in cancer treatment and medical-grade sterilization.

There are a few ways in which humans are able to harness electromagnetic radiation directly from the sun. Due to Earth's ozone layer, the atmosphere becomes opaque to radiation with wavelengths less than 300 nanometers. This allows some ultraviolet radiation to pass through and all of the visible spectrum to reach Earth's surface. Ultraviolet radiation is most well-known for producing a sunburn on the human skin when the waves pass through the atmosphere. The production of vitamin D in the human body is catalyzed by ultraviolet energy from the sun.

Solar Composition

Similar to other stars in the main sequence stage of their lives, the Sun is comprised mainly of hydrogen and helium atoms. Hydrogen was produced shortly after the Big Bang and helium was produced a few minutes after hydrogen as well as in the cores of stars using hydrogen as building blocks. The composition of the Sun also includes elements heavier than helium, all originating from the cores of other stars that have previously dispersed their atoms in supernovae explosions. These other atoms were trapped within the stellar nebula that created the Sun and all of the planets in our solar system. It has been measured that 92.1% of the atoms within the Sun are hydrogen, 7.8% of the atoms are helium, and heavier elements account for 0.1% of the total number of atoms.[24] Although the relative abundances show that hydrogen greatly outnumbers all other atoms in quantity, the profile based upon total mass appears very different due to the light mass of hydrogen. Hydrogen accounts for 71.54% mass of the Sun, helium makes up 27.03% of the mass, and all heavier elements constitute 1.4% of the sun's mass.[25] This percent abundance and mass changes over time due to the process of nuclear fusion, which creates helium atoms from hydrogen atoms.

When comparing the chemical composition of the Sun to that of Earth, both of which were made within the same nebula 4.6 billion years ago, there are notable differences. Hydrogen is about one million times more abundant than iron in the Sun, yet iron is a main component of Earth's crust.[26] Helium, the second most abundant element in the Sun, makes up more than a quarter of the Sun's mass but is extremely rare on Earth.[27] The lightest elements coalesced during the formation of the Sun, leaving mostly the heavier elements to form the planets.

Star Life Cycle and Life Span

The lifespan of a star is highly dependent on the star's initial mass. The greater the mass, the shorter the life of a star. Although a more massive star contains more hydrogen atoms for nuclear fusion, such stars require more energy to maintain their internal temperature and pressure, and therefore fuse their hydrogen fuel at a more rapid pace. The lifetime of a star is limited to the time it takes the star to fuse twelve percent of its hydrogen into helium.[28] For this unit, the focus will be on stars with a similar mass to our Sun.

The Sun was formed 4.6 billion years ago in a stellar nebula. Once fusion began, the Sun would have been classified as a star. The Sun's current status is considered to be in the main sequence of its life cycle. It continues in this stage for the majority of its life. Ninety percent of stars in the Milky Way galaxy are within the main sequence stage.[29] As discussed in the previous section, the Sun has converted only a small fraction of its total original mass into energy over the 4.6 billion years of its life thus far, yet this conversion has already affected thirty-seven percent of hydrogen in the core.[30] In approximately seven billion years from now, the Sun will have run out of fusible hydrogen in the core and nuclear fusion will temporarily cease.[31]

Once hydrogen runs out, the star will have a collapse of its core, creating higher temperatures and pressures, prompting the fusion of helium to begin. The compression of the core causes the star to become brighter and the outer layers to expand outwards.[32] This stage of a star's life is a red giant, or super red giant for stars more massive than our Sun. Helium atoms will combine to create carbon atoms and release energy. Unfortunately, the fusion of helium into carbon will only last about 35 million years compared to the 12 billion year-long main sequence fueled by hydrogen fusion.[33]

After there is no more helium to fuse, the core temperature and pressure are unable to become great enough to fuse carbon atoms. At this point, the star will release its gases in a planetary nebula and only a white dwarf will remain. No fusion takes place beyond this point and the star is considered to be dead. Only the photons still trying to escape from the core from previous nuclear fusion reactions will continue to travel outwards resulting in the emission of visible light.

Stars with a mass much larger than our Sun experience a slightly different life history pattern. After moving rapidly through the main sequence, large and giant stars move into the super red giant stage where they will fuse helium into carbon, nitrogen, oxygen, magnesium and other heavier elements until iron is produced. The production and attempt at fusion of iron atoms cause the star to explode in a violent supernova. Iron is unique in that it absorbs energy from the star rather than releasing energy when attempting to fuse atoms together. This occurs because iron is the most stable element and does not change easily. As a result, the core collapses in less than one second, bounces, and then explodes as a supernova, as bright as a billion suns.[34] A supernova creates temperatures and pressures that permit fusion of elements beyond iron, creating elements with atomic number twenty-seven, cobalt, through atomic number ninety-two, uranium. It is through the explosion that these elements are spewed into space and trapped in neighboring nebulas. Out of one of these nebulas came our Sun and its planets. This explains the origin of the heavier elements found in the Sun and the planets, including Earth. Depending on the original mass of these larger stars, it will alter the final resting stage. Stars five times the solar mass will finish their lives as a neutron star while stars ten times the solar mass will end up as a black hole.

Spectroscopy

An element's spectrum can be observed in multiple ways, this unit focuses on the use of a spectroscope or spectrometer. As the radiation passes through the spectrometer, the photons whose energy correspond to a difference between atomic energy levels are absorbed or emitted leaving a distinct fingerprint.[35] Each line produced will exhibit characteristics of a specific color and therefore wavelength. The unique spectrum is associated with the energy levels of its orbiting electrons.[36] Shorter wavelengths refract, or bend, more through a prism or spectrometer than do the longer wavelengths, therefore creating a spectrum of light.[37]

Scientists use spectroscopy to identify the chemical compositions of stars, including that of our Sun. Not all of the apparent wavelengths match the true values of the element's spectra but this is due to the motion of stars. Most objects in space are redshifted, which means that the wavelengths observed are shifted slightly towards the red end of the visible spectrum due to the source of light moving away from the observer. Knowing the true wavelengths of spectral lines from laboratory experiments, scientists are able to use the observed wavelengths to determine the radial velocity of stars and galaxies as they move through space.[38] The Doppler effect explains that the faster a star or galaxy is moving, the greater the spectral lines are going to be shifted. Astronomers observed different colored stars and each emits different spectral lines. White stars produce strong hydrogen lines, while blue stars produce strong helium absorption lines, and yellow stars like our Sun emit lines where calcium and other heavier elements are strongest.[39] Although hydrogen is the most abundant element in main sequence stars, the brightest spectral line sequence is based upon the temperatures of the outer layers. For example, the calcium spectral line sequence appears strongest in our Sun, although Hydrogen makes up seventy-four percent of the solar mass.[40] The strongest hydrogen spectral lines have wavelengths too short to be classified as visible light and would be better observed in ultraviolet wavelengths.[41] Stars displaying prominent hydrogen lines, like the white stars, typically have moderate photosphere temperatures.[42] The spectrometers only measure visible light waves which range between 400 and 700 nanometers and therefore only provide a portion of the overall picture.

Teaching Strategies

This unit is designed to incorporate the school's literacy focus and create a scientific story for students to understand the many intricacies of the Sun and other stars. The literacy initiative requires students to read, write, speak, and listen at a proficient level in accordance with PSAT and SAT scores. Eleventh-grade integrated science students participating in this unit will be assessed on their content knowledge by a district-mandated unit assessment and their literacy skills by the PSAT and SAT. These results will then be used to measure the effectiveness of teachers. To comply with the school-wide implementation to improve literacy, the unit contains multiple reading, writing, listening, and speaking opportunities for students. The unit scaffolds from the basics of solar structure and composition to solar energy production and emission and the detection of this energy. Students produce a written response based on our class model, explaining how the energy generated in stars is influenced by the composition, structure, and age of stars and how it is observed by humans.

Schoology is the learning management system used by the entire school district for teacher collaboration, student learning, and professional development. The two courses I teach—biology and integrated science—utilize Schoology on a daily basis for students to access course resources, assignments, and assessments. This integrated science unit will be structured electronically with “completion rules” requiring students to move through the unit in a specific fashion. This enables students to scaffold their own learning with periodic checkpoints and instructor feedback throughout the unit. Students will not be free to explore all content simultaneously due to the completion rules. Too much information can create unintentional confusion for students. The intention of the rules is for students to be walked through the lessons in a systematic approach where one topic will build upon the next without the direct instruction from the teacher. All of the courses I teach are designed to be self-paced with strict deadlines for students to practice time management – an important 21st century skill.

Blended learning focuses on the integration of technology to create a personalized learning experience for students. The teacher provides a set of resources. In this case, resources will consist of videos, simulations, articles, and hands-on experiences, and students have a choice in the time, path, place, and pace of their learning. Students are able to complete lessons both in and out of the classroom utilizing resources that best fit their learning style while moving at a pace comfortable to the individual. This type of learning experience allows students to practice various 21st century skills: extracting pertinent content from resources, using technology as a source of information, obeying deadlines, organizing and applying found information, and self-assessment.

Although students will be working primarily at their own pace, there is ample time for peer collaboration. Groups of students will conduct a laboratory experiment to observe spectral emission lines from various light sources. Analysis questions will be answered as a small group to encourage discussion. The illustration of the solar layers is also completed in groups in anticipation of an individual writing component. While working individually, students will be free to work around peers to promote the discussion of content.

The Next Generation Science Standards ask students to construct and communicate explanations based on evidence through writing and modeling. Written responses are collected through Schoology as informal assessments for the instructor to gauge student progress, this knowledge will eventually be incorporated into the culminating writing assignment. All written responses will be graded on a rubric that students have access to prior to writing highlighting expectations. The model students create are represented in a poster with all of the layers of the sun and the changes in electromagnetic energy as it moves through the solar layers.

Classroom Activities

Group Modeling of the Sun

This section of the unit lays the foundation for student reference through the remaining sections. The structure of the unit encompasses a background reading on the basic explanation of $E=mc^2$, class discussion of Einstein's famous equation, graphic organizer which should be reviewed as a class in the form of a lecture, group modeling activity, and written response assignment. The knowledge learned in this section will allow students to better comprehend the process of fusion, wave-particle duality of energy, and how the energy generated in the core of the sun can be accessed by humans; all topics covered in the remaining sections of this unit. The instructor is prepared to discuss and further explain the meaning of $E=mc^2$ – representation of variables and how it only requires a small amount of mass to create large amounts of energy. This discussion is only to support the article students have read and a more in-depth explanation of fusion takes place during the lecture portion of the unit.

In regards to student knowledge on the individual layers of the sun; students are responsible for the relative temperature of each layer and the motion of particles through the layer. Content is accessed by the student through teacher-provided resources on Schoology. These resources should include a variety of texts, such as articles, videos, and simulations, where students can choose the way in which they learn best. The overall goal of this introductory unit is for students to create a graphic organizer identifying the layers of the Sun, the motion of photons, and the temperature of each layer in relation to those surrounding it. The teacher facilitates a review of content that students should have gathered during the individualized notes section. It is during this review that the instructor models the process of fusion by using the example of combining four hydrogen atoms to create one helium atom to create energy. This will connect the relationship of matter and energy.

The model is created by teams of three to four students, predetermined by the instructor, to illustrate student understanding of fusion and explain the movement of photons through the layers of the sun. The diagram includes the layers of the sun in order, a brief description of the layer, and how energy is transported through the individual layer. The diagram also includes the students' interpretation of the process of fusion.

Individual Writing Assignment

The written response is completed individually for students to communicate through writing their understanding of energy and its relation to the sun. The group diagram is the only resource students are able to use to refer back to. As this is the first major writing assignment for students in Integrated Science, a writing modeling activity and peer-review session are made part of the writing process. Prior to the writing of the individual assignment, students review sample writing passages in pairs and then as a class to identify positives and negatives for each. This exercise gives students a clearer focus on how evidence and reasoning are incorporated to support the answer of a question. After the writing session, students anonymously grade three peers' paragraphs and the comments are then returned to the original owner for revision. The writing assignment is graded based upon a CER (Claim, Evidence, Reasoning) rubric.

Mass Versus Lifespan Modeling

Once students have an understanding of fusion, the class demonstrates how the life span of a star relates to the initial mass of the star and the rate of fusion that occurs within the core. A simple demonstration has students hold a low mass object in one out-stretched hand and a higher mass object in the other out-stretched hand. The objective is for students to observe that a lower mass object requires less energy for the student to keep their arm out-stretched while a higher mass object causes the student's arm to become tired more quickly. A class discussion is circumvented back to the idea of fusion being the fuel source and the more massive stars will fuse hydrogen atoms at a faster rate than lower mass stars.

Researching the Electromagnetic Radiation

Students study the electromagnetic spectrum briefly in ninth-grade. This content is re-visited in this section of the unit. Students are to create a graphic organizer, separate from the one made for the layers of the sun, identifying practical uses for each of the waves. Resources are picked by the instructor for students to view based on reading level and content. Although not all of the wavelengths emitted from the sun reach the earth's surface, all of the waves have practical value to human society; either direct from the sun or when generated on earth. This content will be reviewed as a class to hear what students have found are practical ways humans use the different electromagnetic waves.

Observing the Visible Spectrum

Spectrometers allow students to observe visible light radiation being emitted by the sun. In lab groups, students will observe multiple light sources, including fluorescent light bulbs and indirect sunlight, identify the wavelengths of each color and ultimately the possible elements found in a light source other than the sun. Student responses may vary based on the light source chosen and how well the spectral lines are represented. It should be noted that depending on how students hold the spectrometers, results may vary. Some students will be able to identify more spectral lines than others, which will alter the results when identifying the elemental fingerprints. The sun is unable to be used as one of these sources in determining elements because students are only able to observe a complete rainbow and not individual spectral lines.

Student Resources

Crash Course. 2015. *Light: Crash Course Astronomy #24*. Retrieved from https://www.youtube.com/watch?v=jjy-eqWM38g

This video is used by students as an introduction to light and spectroscopy.

ScienceAtNASA. 2010. *Tour of the EMS 01 – Introduction*. Retrieved from https://www.youtube.com/watch?time_continue=2&v=lwfJPc-rSXw

This video is used as a student resource to understand the parts and uses of the electromagnetic spectrum.

Appendix 1

Next Generation Science Standards

HS-ESS1-1. Develop a model based on evidence to illustrate the lifespan of the sun and the role of nuclear fusion in the sun's core to release energy in the form of radiation.

This standard is addressed as a class through student modeling.

HS-PS4-3. Evaluate the claims, evidence, and reasoning behind the idea that the electromagnetic radiation can be described either by a wave model or a particle model, and that for some situations one model is more useful than the other.

Students look at the wave characteristics that photons exhibit as they travel through the Sun and then complete a writing assignment that addresses the behavior of photons as radiation within each layer of the Sun.

HS-PS4-5. Communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy.

This standard is addressed by students in the research segment of the unit. Students study the various ways in which humans communicate and manipulate electromagnetic radiations.

Common Core Literacy Standards

WHST.9-12.2 Write informative/explanatory texts, including the narration of historical events, scientific procedures/experiments, or technical processes.

Students communicate the generation and subsequent flow of energy through the Sun and ultimately to Earth through a writing prompt.

Notes

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