A Study of the Stars: How Everything in Sight Came from the Stars

Allison L Diodati

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 to attend the school. 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 students. Unlike many vocational schools, St. Georges enrolls all students full-time, meaning they 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 the 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 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 that 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. All lessons must be developed so that students with a wide range of ability and background knowledge will be successful, but also challenged.

Rationale

This is my first year participating in the Delaware Teachers Institute (DTI). Through DTI, I hope to first and foremost increase my content knowledge in the area of astronomy. My seminar, *The Universe: It's Full of Star*s, has the opportunity to provide me with a deeper understanding of topics recently incorporated in an astronomy subsection of my Physical Science course. With the implementation of the Next Generation Science Standards (NGSS) in public schools across the state of Delaware, course content in the ninth-grade curriculum has been redesigned to add more of an astronomy component. I hope this deeper 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 also be passed on to other teachers throughout the state via DTI.

With the development of my unit, I plan to focus on NGSS standard HS-ESS1-3: Communicate scientific ideas about the way stars, over their life cycle, produce elements. I currently cover this standard in my Physical Science course, but as mentioned above, the content is relatively new, so I hope to create a solid lesson that incorporates components of technology, student discovery, and collaboration. St. Georges is currently implementing initiatives in the areas of technology and literacy, so I plan to develop a lesson that incorporates both of these in a cohesive manner. In order to discuss NGSS standard HS-ESS1-3 to the fullest extent, I must also touch on HS-ESS1-1: Develop a model based on evidence to illustrate the life span of the sun and the role of nuclear fusion in the sun's core to release energy that eventually reached Earth in the form of radiation. In order to fully comprehend standard HS-ESS1-3 students must have background knowledge of what fusion is and how it relates to the processes that occur in the sun. The beginning activities in my unit will relate to the definitions of fission and fusion, and what the differences are.

Student Learning Objectives

According to the NGSS guidelines, students must be able to relate the life cycle of stars to the creation of elements in the universe. In order to accomplish this, students must acquire a foundational understanding of what fusion is. The first important objective of the unit is for students to be able to describe the process of fusion. In order to accomplish this, I expect to have students define both fission and fusion, and describe similarities and differences between the two processes.

I then plan to have students work collaboratively to conduct an investigation into stars of assigned masses. This will lead them to discover that these stars will in fact produce elements via nuclear fusion and potential supernovae. Each group will be assigned a star to research, and they will be asked to report their findings to the class with a presentation.

For their research, students will be given a list of suggested sources, which will give them the option of finding their information through articles and/or videos.

A third major objective of this unit is to understand that, although fusion results in different element nuclei, the total number of protons plus neutrons combined is conserved. This unit comes directly after the topic of atomic structure, so students will be able to link prior knowledge and apply it to fusion in stars. To present this information to students, I plan to use computer simulations and hands-on activities which will demonstrate the process of nuclear fusion.

A fourth and final objective essential to this unit is the idea that stars can be analyzed by looking at electromagnetic emission and absorption spectra. Computer simulations and class demonstrations will be the most useful methods of instruction for this topic. This will allow students to determine a star's composition.

Key Learning

According to the Next Generation Science Standards, there are a number of Disciplinary Core Ideas (DCIs) and Crosscutting Concepts (CCCs) that align with NGSS standard HS-ESS1-3. After completing this unit, students will describe that hydrogen, helium, and a small number of other light nuclei were formed during the beginning stages of the universe. The helium and other light nuclei, such as lithium, were formed from collisions of subatomic particles. Based on the mass of the star, different elements will be produced during various stages of its life cycle, producing elements as heavy as iron via fusion in their core. Elements heavier than iron are produced from supernova explosions of massive stars, which also redistribute the atoms into space. Finally, students will be able to describe that electromagnetic emission and absorption spectra are used to determine a star's composition at the surface.

NGSS HS-ESS1-1 is not a required standard of St. Georges physical science curriculum, but will be partially covered throughout the course of this unit. Disciplinary Core Ideas (DCIs) and Crosscutting Concepts (CCCs) from this unit that align with NGSS standard HS-ESS1-1 include using evidence to describe that hydrogen is the sun's fuel and that the products of the fusion reaction occurring inside the sun are helium and energy.

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. The Unit Essential Question is as follows: "How do stars produce elements throughout their life cycle?" while the four Lesson Essential Questions are: "What are the similarities and differences of fusion and fission?" "How is nuclear fusion involved with keeping a star alive?" "How does mass of a star impact the elements produced?" and "How can star composition be determined?"

Unit Content Objectives

Student Prior Knowledge

This unit falls near the beginning of a semester long course. At this point, students would have received information regarding a variety of chemistry-related topics including what matter is, chemical and physical properties/changes, layout of the periodic table, history of the atomic model, atomic structure, and isotopes. Essential background information for students to become successful with the content of this unit is as follows:

Matter
The concepts of fusion and the creation of heavy elements are difficult to understand without background information regarding what matter itself is. Many students come to high school with an understanding of what matter is from their middle school science courses, but as previously mentioned, St. Georges is in somewhat of a unique position in that it receives students from all over New Castle County. Because of this, students begin their high school experience with a wide range of background content knowledge. Some students are unfamiliar with what matter is, so it must be reviewed. We briefly discuss that matter is anything that has mass and takes up space. At the end of the lesson, students have an understanding that everything around them is made of matter.

Layout of the Periodic Table

To be able to understand the order elements are created, students must be familiar with the relative masses of the elements being produced, and therefore familiar with the general layout of the periodic table. When discussing the layout of the periodic table, students learn the placement of metals, metalloids, and nonmetals, and the general trends in reactivity, atomic mass, and atomic number. Periodic table groups, such as alkali metals, alkaline earth metals, transition metals halogens, and noble gases are also discussed. Understanding the relationship between atomic number and atomic mass becomes beneficial when discussing how fusion results in the creation of heavier elements.

Atomic Structure

Knowledge regarding atomic structure is an essential component in order to be able to understand fusion. 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 in the final portion of the unit, students must understand the electromagnetic (EM) spectrum. Absorption spectra of elements can be used to assist in determining the composition of stars. To understand absorption spectra, however, students must be familiar with electromagnetic radiation and the visible spectrum. Although students should be familiar with the EM spectrum leaving middle school, 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 may also need to be reviewed at this point, depending on student prior knowledge regarding waves.

Key Unit Content

Fusion

Fusion reactions in the sun convert approximately 600 million tons of hydrogen to 596 million tons of helium every second.[4] The four million tons of "disappearing" mass results in enough energy to sustain life on Earth. During fusion reactions, nuclei from to atoms combine together to form a larger nucleus. Fusion is considered a nuclear reaction, which means the nuclei themselves undergo changes to transform into completely new elements. This differs from chemical reactions, which include the same elements on each side of the reaction, just rearranged into different compounds. The particular fusion reaction occurring in the sun begins with two hydrogen nuclei, simply two protons, coming together to form a deuterium nucleus, consisting of one proton and one neutron. A positron and a neutrino are released in this process.[5] A lone proton must collide with the deuterium nucleus to produce tritium, also known as hydrogen-3, and gamma radiation. Both of these steps must occur twice, and the two resulting tritium nuclei must fuse together to form helium-4, which also release two protons.[6] Helium-4 contains two protons and two neutrons, resulting in a mass number of four. The mass number indicates which isotope of a certain element you have. For example, helium-3 would indicate a mass of three. Helium-2 would have two protons and one neutron. Isotopes of the same element will all have the same number of protons but different numbers of neutrons. Understanding the concept of isotopes is necessary for comprehending the steps in the proton-proton chain described above. Isotopes are discussed with students during the chemistry background unit that precedes the star unit.

During hydrogen fusion, six total protons enter the reaction, and one Helium-4 atom is obtained at the end. Two of the six protons are recovered during this process, indicating the net reaction involves 4 protons transforming into a single He-4 atom. According to the mass of a proton in the periodic table and multiplying by four, it can be seen that this does not align with the mass indicated for the nuclei of a He-4 atom. The "missing mass" is released as gamma rays and subatomic particles (neutrinos and positrons), which provides the energy released from the sun. The helium nucleus produced is 0.7% smaller in mass than that of the four protons which entered the reaction, and according to Einstein's famous $E=mc^2$, the mass has been converted to energy.[7] To ensure the information delivered to the ninth-grade students remains grade-appropriate, certain subatomic particles such as neutrinos and positrons will not be discussed in any detail during the lesson, but simply mentioned as important particles emitted in the process of hydrogen fusion.

Fusion is able to occur inside the sun as a result of a delicate balance between pressure and gravity. Stars form from a collection of gas and dust in space called a nebula. The gas and dust begin to contract, and over time gravitational potential energy (GPE) is converted into thermal energy, heating up the collection of material. Over time, the temperatures become high enough for fusion to begin. The energy released by fusion causes pressure to counteract the inward pull of gravitational forces, and the star remains "alive" as long as this balance remains in-tact.[8]

A high-achieving student may realize that protons are all positively charged, and therefore have an urge to repel one another. Logical thinking may lead a student to wonder how protons are able to resist this urge and combine with one another. The simple answer relates to the significant temperatures inside stars. The sun has internal temperatures of 15 million K, which are high enough to ionize atoms, turning the gas into plasma.[9] The hydrogen ions in the plasma (simply individual protons) are moving at such high speeds, they are able to counteract the electromagnetic forces and allow the strong nuclear force to pull the protons together, forming larger nuclei. The strong nuclear force is a particularly strong force that only works over very small distances to bind subatomic particles together in the nuclei of atoms.[10]

Fusion requires such high temperatures that it does not occur naturally outside of research laboratories on Earth. Because of this, it is helpful for students to gain an understanding of the term fission in addition to fusion. Fission is a process students are more likely to be able to understand, since they are likely to have seen have seen the cooling towers of Hope Creek Nuclear Generating Station in Lower Alloways Creek Township, New Jersey. St. Georges is located within ten miles of the nuclear power plant, and the cooling towers can be easily seen from a bridge near the school. Fission is essentially the opposite of fusion, occurring when a neutron hits a large atom such as uranium or plutonium and forces it into two smaller atoms. This process releases energy as well as neutrons, which then begin a chain reaction of fission with other large atoms.[11]

Low-Mass Star Life Cycle

With as many stars as there are in the universe, scientists are bound to run into stars with a wide range of masses. A vast majority of the material from this unit relies on an understanding of the various life cycles a star may travel through, which is dependent on star mass. The stages a star will enter throughout its life cycle determine the specific elements the star will form. In order to classify stars based on mass, scientists often use a classification system that allows us to compare other stars with the mass of our sun. Stars are often considered low-mass when they are less than two times the mass of our sun. Intermediate-mass stars have a mass between two and eight times the mass of the sun, and high-mass stars are those with masses between eight and one-hundred times the mass of the sun.[12] The boundaries used to classify each type of star might seem like a strange choice at first glance, but they correspond roughly to first the limit at which the stars are not magnetically active, and second to the limit at which stars explode in supernova and form neutron stars and black holes at the end of their lives.

Low-mass stars similar to the sun have a relatively long life cycle when compared to stars with larger masses. This is due to the lower temperatures, and therefore pressures, necessary to counteract the inward pull of gravity. With greater mass comes a greater force of gravity, and fusion must occur at a higher rate in order to keep the temperature and pressure high enough.[13] Because fusion can occur at slower rates in smaller mass stars, the hydrogen is “burned” slower, leading to a longer life cycle. The sun, at 4.5 billion years, is approximately halfway through its 10-billion-year life cycle.[14] Hydrogen fusion occurs during a stage called the main sequence, which is the stage a star spends most of its life in. For the majority of low-mass stars, the main sequence is largely uneventful. The star will, however, become slightly brighter over time. As hydrogen is converted into helium, the number of independent particles in the core is reduced. As this occurs, the core must contract and heat up to remain in balance with the gravitational pressure. This in turn causes the star to become brighter.[15]

Once the star runs out of the hydrogen fuel, the force of gravity will no longer be counteracted and the star’s core will begin to shrink. When this occurs, the outer layers actually expand and the star’s surface temperature will decrease. Eventually, the star’s luminosity will increase as well. For a period lasting approximately 10% of the time the star remained in its main sequence, the star will be considered a red giant.[16] Red giants form due to the presence of hydrogen fusion outside the core of the star. Once the core’s hydrogen has all been fused to helium the star begins to contract. The hydrogen outside of the core in other areas of the star’s gases, referred to as the shell, begins to move near the core of the star. Pressure eventually increases enough that a process called hydrogen-shell fusion is able to occur. This causes fusion to occur at a higher rate than was occurring in the core of the star, therefore increasing the size, core temperature, and luminosity of the star.[17] It is important to note that the red color of the star occurs due to the lower surface temperatures. The surface temperatures are low because of the sheer size of the red giant, even though fusion inside the star is causing the temperatures near the core to increase.

Towards the end of the red giant stage, temperatures of low mass stars similar to our sun will reach 100 million K.[18] These temperatures are high enough to allow the helium nuclei remaining in the core of the star to begin fusing with one another in a process often referred to as the triple alpha reaction.[19] In the triple alpha reaction, three helium nuclei (often referred to in nuclear reactions as alpha particles) fuse together to from one carbon nucleus. In this reaction, the number of protons and neutrons entering the reaction equal the number utilized to produce the carbon nucleus, but the mass of a carbon atom is slightly less than that of three helium nuclei. According to the equation $E=mc^2$ energy must be released. This process causes the star to reduce in size and increase in surface temperatures, returning the star to its original yellow color. Helium-to-carbon fusion will continue for approximately 1% of the star's 10-billion-year life cycle[20] Once the helium inside the core runs out, a helium shell forms around the core of the star, and helium fusion occurs in this shell. At the same time, hydrogen fusion is still occurring outside of the helium shell.

A low-mass star similar to our sun will end its life as a planetary nebula. In a planetary nebula, the outer layers of the star will be ejected into space. The extremely hot carbon core will then be exposed and emit ultraviolet radiation into space. As the radiation is emitted, it will have enough energy to ionize the gases from the outer layers of the star, creating a beautiful display of colors. After about 100,000 years, the planetary nebula will fade and the hot inner core will be left as a dense white dwarf. Over time, the white dwarf will eventually strop emitting light and become dark.[21]

Intermediate and High-Mass Star Life Cycles

The first few stages of intermediate and high-mass stars are similar to those seen in lower mass stars. The main sequence fuses hydrogen to helium, but carbon, nitrogen, and oxygen can also be formed. This allows hydrogen fusion to occur at much higher rates, increasing temperatures enough that protons are able to collide with carbon, nitrogen, and oxygen nuclei, increasing the speed that the life cycle will progress.[22] Stars with intermediate and high masses will form a red supergiant phase as opposed to a red giant phase. It is at this stage that intermediate and high-mass stars differentiate themselves from one another. Intermediate-mass stars will not reach high enough temperatures to develop anything larger than carbon or oxygen, and will end as white dwarfs, similar to those of low-mass.[23]

High-mass stars, however, do reach temperatures high enough to fuse carbon into heavier elements. Temperatures can reach 600 million K, allowing for fusion of elements up to iron.[24] This occurs via a similar process to the hydrogen and helium shell fusion discussed in the low-mass star section, with a cycle of contraction and rise in temperature after each successive element is fused together. Iron, however, is the last stop for element fusion in the core of a star. Fusion is able to produce energy because of the difference in mass from reactant elements to product elements. Up until this point, the product has had a total mass slightly smaller than the total mass of the reactants. Fusion of iron to produce heavier elements, however, does not result in this same difference in mass. Elements heavier than iron will have a mass higher than the iron nuclei necessary for the reaction to occur. This, in turn, will require an input of energy as opposed to creating an output of energy, which will very quickly result in the end of the star, a supernova.[25]

For a supernova to occur, the gravitational pressure must become high enough to allow electrons to combine with protons, turning them in to neutrons and releasing neutrinos. Because there are no longer electric forces to keep the subatomic particles apart, this quickly results in a collapse of the star into an extremely dense ball of neutrons.[26] The collapse releases enough energy to cause a massive explosion of the star's outer layers, resulting in the creation of essentially all other elements through fusion at extremely high temperatures. Over time, the debris from the supernova is able to collect with other dust particles in space to turn into new stars, planets, or other space objects.

Examples of Stars in Various Stages

As a component of this unit, students will research a real star, determine its mass in comparison to the sun, and explain the life cycle their assigned star will follow. According to the article, "*What are the most famous stars?"* by Elizabeth Howell, the following contains information regarding some of the most well-known stars, along with essential information students should find for each: Sirius is not only the brightest star in the constellation Canis Major, but the brightest star in the night sky. It is actually comprised of two stars, Sirius A and Sirius B. Sirius A is currently a main sequence star, while Sirius B is a faint white dwarf.[27] Sirius A is 2.0 times the size of the sun, while Sirius B is 1.0 times the size of the sun.[28] The Alpha Centauri System consists of three stars, Alpha Centauri A, a main sequence star with a mass of 1.1 times the size of the sun, Alpha Centauri B, an orange subgiant with a mass of 0.97 times that of our sun, and Proxima Centauri, a red dwarf with a mass of 0.12 times the mass of the sun.[29] Betelgeuse, a member of the Orion constellation, is currently a red supergiant.[30] It is 20 times the mass of the sun.[31] Rigel, like Betelgeuse, is a multistar member of the constellation Orion. Rigel consists of two stars, Rigel A and Rigel B, which consists of two stars itself. Rigel A is a blue-white supergiant 21 times more massive than the sun. Rigel B consists of Rigel B and Rigel C. Rigel B is 2.5 times the mass of the sun, while Rigel C is 1.9 times the mass of the sun. Both stars are main sequence blue-white sub dwarfs. [32] Vega is a member of the Summer Triangle constellation and is the fifth brightest star in the night sky. It is in its main sequence, with a mass 2.1 times that of the sun. [33] Pleiades, also known as the Seven Sisters, is known as a star cluster. Although seven of the stars can be seen with the naked eye, there are over 1,000 total stars in the group. The brightest of the stars are in their main sequence and are very hot blue stars, while many of the stars in this group are brown dwarfs with masses much smaller than the mass of the sun. [34] Antares has a mass 17 times larger than the mass of the sun, and is currently in the red supergiant phase.[35]

Determining Elemental Composition of Stars

Spectral lines are a significant tool used by astrophysicists to analyze interstellar objects. Scientists have classified the spectra of light in three categories: continuous spectra, absorption spectra, and emission spectra. A continuous spectrum occurs from a light source that provides a continuous rainbow of color, such as an incandescent light bulb[36]. Certain sources of light, such as a warm cloud of gas can emit very specific wavelengths of light. These wavelengths of light appear on emission spectrum as colored bars in specific locations on a black background. This is called an emission spectrum. The wavelengths of light are dependent on the specific elements in the cloud of gas. When atoms absorb energy, that energy has the ability to move electrons from their ground state to an excited state, meaning they move from lower to higher energy levels. The electron is unstable in this position and very quickly moves back down to its ground state, releasing energy in the process. This energy is released as a photon of a specific wavelength. Depending on the wavelength, a specific color of visible light may be emitted. The third type of spectra, absorption spectra, essentially shows the inverse of the emission spectra. If a light source emitting a continuous spectrum of color is blocked by a cool cloud of gas, that cloud will absorb specific wavelengths depending on the elements inside that cloud. SOURCE. The result is a continuous spectrum of color with black bars interspersed. These black bars align with the wavelengths of light absorbed by the gas cloud.

Analysis of emission spectra is especially useful for scientists as they study the composition of stars. Depending on the makeup of the stars, different spectral lines will be seen. This can give scientists an indication of what elements are present at the surface of the star. One challenge, however, of using spectral lines to determine star composition, is that two specific conditions must be met in order for the spectral lines to be present. The first is that the element must be present in the outer atmosphere of the star, and the second is that the temperature must be correct for the electron movement to emit a wavelength within the visible spectrum of electromagnetic energy[37]. For example, certain stars have relatively low temperatures that will not provide enough energy to move an electron to the energy state necessary to emit visible light. This results in very few, if any, hydrogen atoms emitting light, which would make it appear that hydrogen is not present in the star. The very nature of star existence relies on the ability to fuse hydrogen atoms together, providing proof that hydrogen must still be present in the star even if it does not appear on the emission spectra. With this knowledge, scientists can use spectrometers to analyze the absorption spectra of stars to determine information regarding their composition.

Teaching Strategies

Ninth grade 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 Physical \cience curriculum 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 third 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 their own self-guided research on their assigned star, 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.

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 learning platform 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: Fission vs. Fusion Research and Poster

Students will work in small teams of three to four students to research the terms fission and fusion. Their goal will be to understand the major differences and similarities between the two reactions. This activity aims to answer the first Lesson Essential Question of the unit: “What are the similarities and differences of fusion and fission?” A basic understanding of the process of fusion is an essential component to understanding how a star continues to remain “alive”. Since many students have likely heard of or seen nuclear power plants by the time they have reached ninth grade, it is worthwhile to discuss how - in many ways - fission, which supplies the energy provided by nuclear power plants, is similar to fusion in certain aspects.

During their research, students will use both the class textbook as well as internet resources to find information regarding the following topics for both fission and fusion and present the information on a poster: a clear explanation of each term, written in students’ own words, a diagram of each process (fission and fusion), with all subatomic particles accurately represented before during, and after the process occurs, a list of elements commonly involved with each process, and real-life examples of each process and where they may or may not occur naturally.

Once students have finished developing their posters, a class discussion will be held to ensure all students have a thorough understanding on the basics of both fission and fusion. Important topics to include in the class discussion are major similarities and differences between the two terms, especially that fusion is a process resulting in collisions between atoms, making successively larger elements, while fission occurs from the splitting of two atoms. The teacher could also explain the reason certain elements are only able to release energy via the process of fusion while others are only able to release energy via the process of fission. It may also be worthwhile to explain why elements including and heavier than iron will not be able to release energy during fusion (outlined in the “Key Unit Content” section above). Students could calculate this by looking at the masses of the reactants and products of the nuclear reactions.

Activity 2: Life Cycles of Stars and the Elements They Produce

Students will be given the name of an actual star (or small group of stars) to research and determine the life cycle of. Possible stars to assign students are outlined in the *"Examples of Stars in Various Stages"* section of the Key Unit Content above. Depending on class size, the teacher may use their own discretion to determine whether this assignment is done alone, in pairs, or in small groups. The goal of this activity is to implement a discovery-based learning approach that requires students to take charge of their own learning. Students will be asked to conduct their own research and develop a presentation for the rest of the class. Depending on the amount of class time available to devote to the project, different options in presentation method may be offered to students. Unfortunately, with the number of topics that must be covered in Physical Science classes at St. Georges, students will be given strict time constraints for this activity. Students will be able to choose presentation methods such as Microsoft PowerPoint, Presi, Canva, or another similar method for developing their presentation. If time allows in your classroom, students may be given the opportunity to design their own video, skit, music video, or news broadcast.

As students conduct their research, they will be asked to first determine the stage of life their particular star is in as well as the mass of the star. Students will then be able to research the general life cycle of any star with a mass similar to their assigned star. They must create a presentation for the rest of the class that provides the following information: the name of star and stage of life, the mass of star relative to other stars, a detailed layout of the life cycle of stars with similar masses to the assigned star, how fusion relates to the star (what elements are fusing in different stages?), and what elements will be produced in which stages.

Students will be required to enter their notes in a Google Doc shared with me, so that I am able to view their information and correct any misconceptions as they work. New Castle County Vocational Technical School District has supplied all students and teachers in the district with Google accounts, so students at St. Georges are familiar with the concept and layout of Google Docs. The teacher may need to ensure all students are familiar with the website before giving the assignment. Addressing student misconceptions prior to the development of presentations is important in this particular lesson, as the students will be teaching other groups who have not obtained the information in any other manner. This can have obvious consequences if the presented information is incorrect. I would suggest that the teacher check in with each group verbally as well, to ensure students comprehend the information they are collecting.

Students will also be required to develop two questions for the audience to answer while their group is presenting. These questions should address what the group believes to be the two most important concepts from their presentation. Each group must submit their two questions to the teacher in advance for approval. The teacher may want to compile all questions onto one printable page, so students are able to answer all questions in one location and retain the sheet for studying purposes after the project is completed.

After presentations, the teacher should conduct a formative check ensure all students have a thorough understanding of what elements are produced in different stages of low, intermediate, and high-mass stars. This can be done via discussion, PowerPoint presentation, or PearDeck presentation. PearDeck is a subscription-based interactive presentation platform, integrated with Google Slides, that allows teachers to develop interactive slides. Slides can be modified to require students to answer multiple choice questions, short-response questions, or to free-draw a response, among other options. Teachers can see student responses in real time, and responses can either be hidden from student view or anonymously posted via a projector. A teacher may use PearDeck to gauge student understanding of concepts addressed in the student presentations.

Activity 3: Analyzing Star Spectra

The third and final activity for the unit involves focusing on the final Lesson Essential Question from the unit: “How can star composition be determined?” Students will complete a Gizmo titled “Star Spectra.” Gizmos are subscription-based interactive simulations that guide students through an activity or experiment based on a designated topic. They are designed by Explore Learning, a company aimed at improving student learning in math and science[38]. As students complete the Star Spectra Gizmo, they will work through the provided Student Exploration Sheet. I highly recommended previewing the Student Exploration Sheet along with the Gizmo and modifying based on student prior knowledge and ability. The Star Spectra Gizmo leads students through a simulation that requires them to click on a variety of stars and analyze their spectra to determine composition. It is important to note that students are analyzing the surface of the star, so they may see more than the simple hydrogen and helium they expect to see. The light emitted at the surface of the star aligns with the elements present at the time of the star’s birth. Explore Learning also provides five analysis questions with each Gizmo for students to answer. Students will be asked to respond to the five questions upon completion of the Gizmo.

The next portion of this activity involves connections between prior activities and star spectra analysis. In the previous unit, students reviewed information regarding the electromagnetic spectrum, which should have been covered in detail during middle school. Visible light was briefly discussed, as well as the properties of light and its behaviors. During this unit, students completed an activity that introduced them to terms such as diffraction, reflection, and absorption. While completing this activity, students were exposed to diffraction using a variety of tools, but most importantly gas-discharge lamps. Students were given an opportunity to view lamps with gases such as helium, oxygen, nitrogen, and hydrogen through diffraction lenses and spectroscopes. At the time, students would have seen the spectral lines without actually realizing what spectral lines are. The lamps would be brought out a second time, with the purpose of making the connection between the spectral lines they see with specific elements in these lamps and the spectral lines of the stars they just finished analyzing during the Gizmo.

Upon completion of the three activities, students will have a thorough understanding of all four Lesson Essential Questions associated with the Unit. A formal test or quiz can be given to determine comprehension of the material.

Summary of Activities

All student activities are closely aligned with components of the Next Generation Science Standards as well as discovery-based learning techniques. A majority of the activities are student-led and require the students to conduct investigations in order to obtain information that answers 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 presentation so they may teach their fellow classmates and answer questions. As for blended learning, this unit incorporates a variety of tasks that utilize traditional instruction techniques as well as technology. The student research, presentation, Gizmo, and potential PearDeck review all require the use of technology, contributing to the use of blended learning in the classroom.

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[1] (Education 2018)
[2] (Ibid.)
[3] (Ibid.)
[4] (Bennett 2017)
[5] (Ibid.)
[6] (Ibid.)
[7] (Ibid.)
[8] (Ibid.)
[9] (Ibid.)
[10] (Ibid.)
[11] (Fission and Fusion: What is the Difference? 2018)
[12] (Bennett 2017)
[13] (Ibid.)
[14] (Ibid.)
[15] (Ibid.)
[16] (Ibid.)
[17] (Ibid.)
[18] (Ibid.)
[19] (Ibid.)
[20] (Ibid.)
[21] (Ibid.)
[22] (Ibid.)
[23] (Ibid.)
[24] (Ibid.)
[25] (Ibid.)
[26] (Ibid.)
[27] (Howell 2015)
[28] (Croswell 2005)
[29] (Howell 2015)
[30] (Bennett 2017)
[31] (Maddalena 1998)
[32] (Howell 2015)
[33] (Ibid.)
[34] (Ibid.)
[35] (Ibid.)
[36] (Bennett 2017)
[37] (Richmond n.d.)
[38] (Gizmos 2018)