A Lesson from Civil Air Patrol's
Aerospace Connections in Education (ACE) Program

Super Stars
Grade 6 Academic Lesson #8

Topic: life cycle of stars (science, language arts)

Lesson Reference: Adler Planetarium and Astronomy Museum Life Cycles of Stars & Black Holes (lesson adapted)

Length of Lesson: 30 - 60 minutes

Objectives:
- Students will realize the relationship between the mass of a star and the star's life expectancy.
- Students will identify colors of the coolest and hottest stars.
- Students will visually demonstrate the life cycle of stars.

Next Generation Science Standards:
- MS-ESS1-1. Develop and use a model of the Earth-sun-moon system to describe the cyclic patterns of lunar phases, eclipses of the sun and moon, and seasons.
- MS-ESS1-3. Analyze and interpret data to determine scale properties of objects in the solar system.

CCSS ELA:
- L 6.6 - Acquire and use accurately a range of general academic and domain-specific words and phrases sufficient for reading, writing, speaking, and listening at the college and career readiness level.

Background Information:
A K-W-L chart is a chart with 3 columns. The heading of the first column is "K," which stands for "know." The "W" should be the heading for the middle column, and this stands for "want to know." The heading of the last column is "L," which stands for "learned." At the beginning of the lesson, students state what they know about a topic and what they hope to learn about a topic. At the end of the lesson, students identify things they learned.

Stars are primarily made up of hydrogen and helium. Stars produce energy through nuclear fusion. According to ThoughtCo.com, "the atoms (often the element hydrogen) inside the star collide together, going through a process of nuclear fusion, which generates heat, electromagnetic radiation (including visible light), and energy in other forms, such as high-energy particles."

It is common to see temperatures of stars recorded in a unit of measurement called Kelvin, such as 10,000 k. Kelvin (to put it simply) is another unit of measurement, just like Celsius and Fahrenheit. When comparing Kelvin and Fahrenheit in terms of star temperatures, a measurement in Kelvin converts to a larger number in Fahrenheit (when looking at high star temperatures). Kelvin units of measurement are based upon absolute zero, the point at which atoms in everything, not just water, stop moving or "freeze." Kelvin is also used to measure the temperature of different colors of light.

The information below is from WorldbookOnline:

A star is a huge, shining ball in space that produces a tremendous amount of light and other forms of energy. The sun is a star, and it supplies Earth with light and heat energy. The stars look like twinkling points of light -- except for the sun. The sun looks like a ball because it is much closer to Earth than any other star.

The sun and most other stars are made of gas and a hot, gaslike substance known as plasma. But some stars, called white dwarfs and neutron stars, consist of tightly packed atoms or subatomic particles. These stars are therefore much more dense than anything on Earth.

Stars come in many sizes. The sun's radius (distance from its center to its surface) is about 432,000 miles (695,500 kilometers). But astronomers classify the sun as a dwarf because other kinds of stars are much bigger. Some of the stars known as supergiants have a radius about 1,000 times that of the sun. The smallest stars are the neutron stars, some of which have a radius of only about 6 miles (10 kilometers).

Stars are grouped in huge structures called galaxies. Telescopes have revealed galaxies throughout the universe at distances of 12 billion to 16 billion light-years. The sun is in a galaxy called the Milky Way that contains more than 100 billion stars. There are more than 100 billion galaxies in the universe, and the average number of stars per galaxy may be 100 billion. Thus, more than 10 billion trillion stars may exist. But if you look at the night sky far from city lights, you can see only about 3,000 of them without using binoculars or a telescope.

A star has five main characteristics: (1) brightness, which astronomers describe in terms of magnitude or luminosity; (2) color; (3) surface temperature; (4) size; and (5) mass (amount of matter). These characteristics are related to one another in a complex way. Color depends on surface temperature, and brightness depends on surface temperature and size. Mass affects the rate at which a star of a given size produces energy and so affects surface temperature. To make these relationships easier to understand, astronomers developed a graph called the Hertzsprung-Russell (H-R) diagram. This graph helps astronomers understand and describe the life cycles of stars. The Hertzsprung-Russell diagram displays the main characteristics of stars. The diagram is named for astronomers Ejnar Hertzsprung of Denmark and Henry Norris Russell of the United States. Working independently of each other, the two scientists developed the diagram around 1910.

Astronomers express the mass of a star in terms of the solar mass, the mass of the sun. For example, they give the mass of Alpha Centauri A as 1.08 solar masses; that of Rigel, as 3.50 solar masses. The mass of the sun is 2 Ž 1030 kilograms, which would be written out as 2 followed by 30 zeros.

Stars that have similar masses may not be similar in size -- that is, they may have different densities. Density is the amount of mass per unit of volume. For instance, the average density of the sun is 88 pounds per cubic foot (1,400 kilograms per cubic meter), about 140 percent that of water. Sirius B has almost exactly the same mass as the sun, but it is 90,000 times as dense. As a result, its radius is only about 1/50 of a solar radius.

Any star -- whatever its mass -- that gets all its energy from hydrogen fusion in its core is said to be "on the main sequence" or "a main-sequence star." The amount of time a star spends there depends on its mass. The greater a star's mass, the more rapidly the hydrogen in its core is used up, and therefore the shorter is its stay on the main sequence. An intermediate-mass star remains on the main sequence for billions of years.

When all the hydrogen in the core of an intermediate-mass star has fused into helium, the star changes rapidly. Because the core no longer produces fusion energy, gravity immediately crushes matter down upon it. The resulting compression quickly heats the core and the region around it. The temperature becomes so high that hydrogen fusion begins in a thin shell surrounding the core. This fusion produces even more energy than had been produced by hydrogen fusion in the core. The extra energy pushes against the star's outer layers, and so the star expands enormously. As the star expands, its outer layers become cooler, so the star becomes redder. And because the star's surface area expands greatly, the star also becomes brighter. The star is now a red giant.

After a planetary nebula fades from view, the remaining core is known as a white dwarf star. This kind of star consists mostly of carbon and oxygen. Its initial temperature is about 100,000 K. Because a white dwarf star has no fuel remaining for fusion, it becomes cooler and cooler. Over billions of years, it cools more and more slowly. Eventually, it becomes a black dwarf -- an object too faint to detect. A black dwarf represents the end of the life cycle of an intermediate-mass star.

High-mass stars, those with more than 8 solar masses, form quickly and have short lives. A high-mass star forms from a protostar in about 10,000 to 100,000 years. High-mass stars on the main sequence are hot and blue. They are 1,000 to 1 million times as luminous as the sun, and their radii are about 10 times the solar radius. High-mass stars are much less common than intermediate- and low-mass stars. Because they are so bright, however, high-mass stars are visible from great distances, and so many are known.

After a Type II supernova blast occurs, the stellar core remains behind. If the core has less than about 3 solar masses, it becomes a neutron star. This object consists almost entirely of neutrons. It packs at least 1.4 solar masses into a sphere with a radius of about 6 to 10 miles (10 to 15 kilometers). Neutron stars have initial temperatures of 10 million K, but they are so small that their visible light is difficult to detect. However, astronomers have detected pulses of radio energy from neutron stars, sometimes at a rate of almost 1,000 pulses per second. A neutron star actually emits two continuous beams of radio energy. The beams flow away from the star in opposite directions. As the star rotates, the beams sweep around in space like searchlight beams. If one of the beams periodically sweeps over Earth, a radio telescope can detect it as a series of pulses. The telescope detects one pulse for each revolution of the star. A star that is detected in this way is known as a pulsar.

If the stellar core remaining after the supernova explosion has about 3 or more solar masses, no known force can support it against its own gravitation. The core collapses to form a black hole, a region of space whose gravitational force is so strong that nothing can escape from it. A black hole is invisible because it traps even light. All its matter is located at a single point in its center.

Low-mass stars, ranging from 0.1 to 0.5 solar mass, have surface temperatures less than about 4,000 K. Their luminosities are less than 2 percent of the solar luminosity. Low-mass stars use hydrogen fuel so slowly that they may shine as main-sequence stars for 100 billion to 1 trillion years. This life span is longer than the present age of the universe, believed to be 10 billion to 20 billion years. Therefore, no low-mass star has ever died. Nevertheless, astronomers have determined that low-mass stars will never fuse anything but hydrogen. Thus, as these stars die, they will not pass through a red-giant phase. Instead, they will merely cool to become white dwarfs, then black dwarfs.

Materials:

- for a class of 30: 12 red balloons, 12 yellow balloons, 4 white balloons, 2 blue balloons (1 balloon for each student in a class of 30) If you do not have 30 students, use the following percentages for the class:
  40% red, 40% yellow, 15% white, and 5% blue
- wooden beads, marbles, round pebbles, or very small wadded pieces of paper
- scissors or pin (to pop balloons)
- red, yellow, and black markers for each student
- Life Cycle of Stars Information Chart (included near the end of this lesson)
- "Colors & Lives of Stars" student copies (one copy included near the end of this lesson)
- dry erase board, chalkboard, or chart paper with appropriate marker

NOTE:

This lesson can be done by providing every student a balloon, as indicated in the materials list, OR it can be completed using four student volunteers at the front of the room. (One student will hold a red balloon, one will hold a yellow balloon, one student will hold a white balloon, and one student will hold a blue balloon.) If only using 4 volunteers, you will only need one set of red, yellow, and black markers.

Prior to beginning the lesson, place one wooden bead, marble, or small wadded piece of paper, inside each balloon.

Lesson Presentation:

1. Create a K-W-L chart on the board or on chart paper. (See background information if you need information on what a "K-W-L" chart is.) Ask students what they know about stars and record their answers under the "K" column. Ask students what they would like to learn about stars and record their answers under the "W" column. To help students identify what they know and what they would like to learn, consider asking some of the following questions:
   - Are all stars the same?

- Do we know how stars form or what makes them shine?
- How long do stars live?
- Do stars live or last forever?
- Are stars close to each other?
- How do black holes form?
- Will the sun turn into a black hole?

2. Tell students that they will learn about the characteristics and lives of stars in this lesson.

3. Distribute a "Colors and Lives of Stars" sheet to each student. While distributing the sheets, ask students to define what a star is. State that because stars are so massive, they have a gravitational pull.

4. Inform students that a star is a ball-shaped gaseous celestial (of or relating to the skies or heavens) body of great mass that shines by its own light. Have them complete the definition on their worksheet.

5. Ask for 4 students to volunteer to stand in front of the class, each with a different colored balloon. (If you are providing a balloon to each student, distribute the balloons and markers at this time.)

6. Explain that the main difference between stars is mass. (Mass is the amount of material that makes up an object.) Astronomers express the mass of a star in terms of solar mass. This measurement compares a star's mass to that of the sun's. Tell the students that the sun has a solar mass of 1. So, an 8 solar mass star (for example) is 8 times more massive than the sun.

7. Guide students in the completion of #2 on their "Colors & Lives of Stars" page. Students should number the colors of stars in order from least massive to most massive, with 1 being least and 4 indicating most massive.
   (Answers: 1=red, 2=yellow, 3=white, 4=blue)

8. Tell students that as they do the balloon activity in class, they will hear answers to the questions on their paper. For example, they know now the answers to the next question. Tell students to follow along carefully in class in order to complete the remaining questions during the lesson.

9. Ask students which balloons they think are the coolest and hottest stars. Tell students that red stars are the coolest and blue stars are the hottest. Tell students to number the temperature of the stars in order from hottest to coolest on question number 5 by writing a 1 beside red, a 2 beside yellow, a 3 beside white, and a 4 beside blue. Ask students what color our sun is. (yellow) Tell students that the sun is the closest star to us. It is about 93 million miles away from Earth.

State that they now know that the sun is only warmer than red stars. Tell students that red stars have a temperature of up to about 6,300 degrees Fahrenheit. The hottest blue stars range in temperature from about 50,000 degrees Fahrenheit to 90,000 degrees Fahrenheit.

10. Ask students which color star they think will live the longest and why.

11. Guide students through the series of steps written on the "Life Cycle of Stars Information Chart." As you call out each new age, write it on the board, and then tell students what to do for the new age of their star (balloon). Also, periodically ask students for their predictions of what they think will happen next. For each age, tell students what to do for their "star" (colored-balloon). Remind them to answer questions on their note-taking sheet as you all proceed.

12. Some helpful vocabulary to include during the continuation of the lesson: (definitions/explanations from NASA)

    - **supernova:** The death explosion of a massive star, resulting in a sharp increase in brightness followed by a gradual fading. At peak light output, supernova explosions can outshine a galaxy. The outer layers of the exploding star are blasted out in a radioactive cloud. This expanding cloud, visible long after the initial explosion fades from view, forms a supernova remnant.
    - **neutron star:** (the imploded core of a massive star produced by a supernova explosion) A neutron star is about 20 km in diameter and has the mass of about 1.4 times that of our Sun. This means that a neutron star is so dense that on Earth, one teaspoonful would weigh a billion tons! Because of its small size and high density, a neutron star possesses a surface gravitational field about 2×10^{11} times that of Earth. Neutron stars can also have magnetic fields a million times stronger than the strongest magnetic fields produced on Earth. Neutron stars are one of the possible ends for a star. They result from massive stars which have mass greater than 4 to 8 times that of our Sun. After these stars have finished burning their nuclear fuel, they undergo a supernova explosion. This explosion blows off the outer layers of a star into a beautiful supernova remnant. The central region of the star collapses under gravity. It collapses so much that protons and electrons combine to form neutrons. Hence the name "neutron star". Neutron stars can be observed as pulsars.
    - **pulsars:** Pulsars are spinning neutron stars that have jets of particles moving almost at the speed of light streaming out above their magnetic poles. These jets produce very powerful beams of light. Like a ship in the ocean that sees only regular flashes of light, we see pulsars "turn on and off" as the beam sweeps over the Earth. Neutron stars for which we see such pulses are called "pulsars", or sometimes "spin-powered pulsars," indicating that the source of energy is the rotation of the neutron star.
    - **black hole:** If the collapsed stellar core is larger than three solar masses, it collapses completely to form a black hole: an infinitely dense object whose gravity is so strong that nothing can escape its immediate proximity, not even light.
    - **nebula** - a cloud of dust particles and gases in space

- **planetary nebula**: Planetary nebulae are ball-like clouds of dust and gases that surround certain stars. They form when a star begins to collapse and throw off the outer layers of its atmosphere. When viewed through a small telescope, this type of nebula appears to have a flat, rounded surface like that of a planet.
- **white dwarf:** For average stars like the Sun, the process of ejecting its outer layers continues until the stellar core is exposed. This dead, but still ferociously hot stellar cinder is called a white dwarf. White dwarfs are roughly the size of our Earth despite containing the mass of a star.
- **black dwarf**: A black dwarf is a white dwarf that has cooled down enough that it no longer emits light. It takes tens to hundreds of billions of years for a white dwarf to cool down entirely, and the universe hasn't been around that long. Therefore there are no black dwarfs yet, but there will be in the future.

13. After all stars have met their fate, review the life cycle of the stars. Emphasize which star died first and last. Ask students what they notice about the mass of the star in relation to how long the star lived. Discuss the fate of the yellow stars like our sun. Note that they live quite a long time and don't become either black holes or neutron stars. Review the formation of black holes. Ask students if the majority of stars become black holes. (no) Black holes are the rarest stars in our group.

Summarization:
To summarize today's lesson, finish the K-W-L chart by asking students what they learned from this activity. List student responses on the chart under the "L."

Character Connection: Tell students that just as there are similarities and differences in stars, there are similarities and differences in people. Just as stars add beauty to our galaxy, people have the opportunity to add beauty to our world. Encourage students to find the strengths in people and be part of making the world a better place. Encourage students to be super stars that shine in the world around them.

Assessment:
- teacher observation
- student answers to class discussion questions
- "Colors and Lives of Stars" worksheet

Additional activity ideas to enrich and extend the primary lesson (optional):
- Have students make and learn to use a star chart. Directions and patterns are available at "How to Make a Star Wheel the Simple Way."
- Complete a star classification activity. Materials are available at Star Light, Star Bright: Exploring How Stars Are Classified.

- For a star sequencing lesson , go to
  Life Cycle of Stars
- Find several activities at
  NASA Sci-Files Teacher Resources
- Middle School Science Blog
- Find several star activities at NASA Astro Venture (go to "Lesson 9: Planetary Temperature as a System").

Associated Websites:

- Great site to learn how stars form and descriptions of stars:
  NASA Universe: Stars
- Questions and answers about stars: NASA: Ask an Astrophysicist
- Learn about Kelvin and temperature:
  Temperature Scales
- Learn more about stars:
  How Stars Work
  NASA: The Life and Death of Stars
  PBS: The Lives of Stars
- You may wish to watch one of the following videos (or choose one to share with your class):
  Learning Physics_Types of Stars by Size, Color and Life Cycle
  The Life Cycle of Stars