Colors of Stars: Teacher Lesson Plan

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Subject: Physical Science

Grade level: 9-10

Rationale or Purpose:

Students observe colors in the flame of a burning candle to explore connections between matter, light, color, and temperature — basic concepts of matter and energy. They elaborate on these basic concepts in a new context of astronomy and stars. When matter gets hot enough, it emits visible light. When heated to the same temperature, light bulb filaments, horseshoes, and stars will emit the same characteristic blend of color (or wavelengths) of light. Stars are different colors — white, blue, yellow, orange, and red. The color indicates the star's temperature in its photosphere, the layer where the star emits most of its visible light.

Student Product:

Students produce color drawings of the candle flame and scale models of stars.

Materials:

- StarDate radio script ("Denebola" or "Spring Triangle")
- Candles and candle holders (e.g., cupcakes)
- Matches
- White paper
- Crayons or colored pencils. Offer students a wide variety of colors.
- Construction paper
- Colored chalk
- String
- Spherical balloons (yellow and white)
- Ruler or meter stick

Objectives:

Texas Essential Knowledge and Skills Objectives
Chapter 112, section 42: Integrated Physics and Chemistry
112.42.6 (H) Energy transformations: analyze the effects of heating and cooling processes in systems (candle flame and stars).

Background

1. Dr. Frank Bash, an astronomer and professor with The University of Texas at Austin Astronomy Department and McDonald Observatory, has written an excellent primer about stars. http://stardate.org/resources/stars/bash.html
2. Additional background information about stars: http://stardate.org/resources/stars/
3. Candle flames in space and on Earth from NASA:
http://liftoff.msfc.nasa.gov/News/2000/News-Flames.asp
4. Microgravity and candle flames: http://www.me.berkeley.edu/mcl/microg.html
5. Microgravity combustion science from NASA:
http://microgravity.grc.nasa.gov/combustion/cfm/cfm_index.htm
http://microgravity.grc.nasa.gov/combustion/cfm/cfm_intro.htm
6. The physics of candle flames: http://www.physics.utoledo.edu/~lsa/_color/indepthFlame.htm

Preparation

1. Choose one of the following StarDate radio program scripts for students to read, or you may read it aloud to them: "Spring Triangle" or "Denebola."
2. Optional: You may wish to check the StarDate Online web site (http://stardate.org) for interesting radio scripts that will help students find stars of different colors in the night sky. See the "Elaborate" section of this activity.
3. Distribute to each group of students: white paper, crayons or colored pencils (lots of different colors), and one candle in a candle holder. Remind students of your classroom's safety rules before beginning.

Activity

Engage

Begin by asking the students what they know about stars. Accept all answers. Depending upon the grade level, they may list simple facts (e.g., we see them at night and they are up in the sky) or more sophisticated facts (e.g., they are in constellations or they are like distant "Suns."). It is unlikely that anyone will mention color or size, except maybe to say that stars are big. But, stars are different colors and different sizes.

Ask students to read, or read aloud, the StarDate script you chose.

Explore

Light the candles. Ask the students to draw what they see in the flame, and to pay special attention to the colors they select. Ask students to record the colors they selected to draw the flame. Some students will use a wide variety of blue, yellow, orange, and red to capture the subtle hues in the flame.

Optional: If you have a digital camera, ask each group to take a picture (flash off) of their candle flame. Use the camera *after* students have completed their candle flame drawings.

Explain

When everyone is finished drawing, ask each group to describe what they saw and respond to the following questions:

1. Which part of the flame do you think is the hottest?

   The blue part is the hottest. Many think that "red" is always the hotter color, so that's what they expect.

2. As you watch the candle flame, what things or events in everyday life come to mind?

   Colors of the flame on a gas stove, camp fire, outdoor charcoal grill fire, rocket engine during liftoff, blowtorch, jet engine…

The answers will usually make the students want to look at their candle flame again, so don't extinguish the flames until all students have reported (unless it becomes a safety issue). Most will notice that the color of the flame is different close to the wick.

Optional: Load the digital images onto a computer to display on a video projector. Each group may refer to these images, as well as their drawings, to describe their flame.

In stars, just as in Earth-bound fires, blue is hotter than yellow, and yellow is hotter than red. The Sun is much hotter than a candle flame. Unlike a candle, the Sun uses nuclear fusion as its energy source, not a chemical reaction like burning oil or wood. Stars are different colors because they are different temperatures. They are all "hot" compared to most things on Earth; they range in surface temperature from less then 3000 K to over 50,000 K.

Explain to students that when we heat things that don't easily melt (like metal), they first look normal, then begin glowing "red-hot," and later become "white-hot."

Elaborate: Draw scale models of stars

Because it is difficult to make three-dimensional models that preserve scale, some of the representations of stars in this activity will be flat. On a sidewalk or parking lot, try drawing colored circles in chalk for the larger stars. You can make the smaller ones out of colored construction paper.

To begin, students blow up a yellow balloon to represent the Sun, then a white one that is 2.7 times larger (in diameter and circumference) to represent Vega (guide students through solving this problem):

- Measure the circumference of the yellow balloon (C_y) using string.
- Calculate the circumference of the white balloon: $C_w = 2.7 \times C_y$
- Cut a new string to the length of C_w
- Blow up the white balloon until its circumference is C_w.

Students make paper disks the same diameter and color as these two balloons. Now, they compute how large the disk would be for the larger stars.

Making a disk to represent a star is like using a flat picture to represent a person. Stars are spheres of hot gas, round like balloons. Students draw the largest diameters outside (using chalk or tracing the outline with string).

To make a circle:

- Measure a piece of string equal to the calculated diameter.
- Fold the string in half and hold at the center
- Place a piece of chalk where the ends of the string meet and trace a circle.

Use the table provided to scale the star diameters. For example, if you begin with a one-centimeter Sun, then Betelgeuse will be 8.3 meters! So, this activity takes a lot of space.

Star	**Diameter** (Sun's diameter = 1)	**Color**
Sun	1	Yellow
Betelgeuse in Orion	830	Red
Antares in Scorpius	775	Red
Vega in Lyra	2.7	White
Rigel in Orion	50	Blue
Proxima Centauri C (closest star to the Sun)	0.03	Red
Dubhe (brightest star in the Big Dipper)	14	Orange

Although stars range in mass from less than one-tenth the mass of the Sun to 100 solar masses, the most massive stars are not the largest. Stars like Betelgeuse and Antares have "puffed up" into red giants hundreds of times the Sun's diameter, yet Betelgeuse is about 20 times more massive than the Sun. There is a lot of empty space inside Betelgeuse. If Betelgeuse is 830 times the Sun's diameter, air at sea level is almost 25,000 times the average density of Betelgeuse.

Evaluate

Explore (20 points)
(20 points) Candle flame drawing: Students represent the flame with a variety of colors, and accurately proportion parts of the flame. Some may include the wick and candle.

Explain (40 points)
1. Which part of the candle flame do you think is the hottest? Why?
(20 points) Students draw on prior knowledge / everyday experience and their understanding of science concepts in their explanations.

2. As you watch the candle flame, what things or events in everyday life come to mind?
(20 points) Students list a variety of things and/or events:
For instance:
jet engine, blowtorch, hot oven, bread toaster coils, camp fire, Space Shuttle launch, the Sun, sunset colors…

Elaborate: Make and draw models of stars (40 points)
Parts 1 and 2: (10 points) Students inflate the yellow balloon to represent the Sun and inflate the white balloon so that its circumference is 2.4 times larger than the Sun balloon.

Parts 3 and 4: (10 points) Students accurately measure and cut out the paper disks, then correctly calculate the scale diameters for the four large stars in the table.

Part 5: (20 points)
Students accurately calculate the model star radii using the table. The radii depend on the scale size they choose for the Sun.
Students use the string and chalk to draw big circles that represent the large stars:

- Measure a piece of string equal to the calculated diameter.
- Fold the string in half and hold at the center.
- Place a piece of chalk where the ends of the string meet and trace a circle.