THINKING AND ACTING LIKE A SCIENTIST

TEACHER'S GUIDE

The Elements of Stars

How do stars produce elements during their life cycles?

GRADES 9–12

Earth & Space

VAN ANDEL EDUCATION INSTITUTE

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INQUIRY-BASED SCIENCE

Earth & Space

The Elements of Stars

Grade Level/ Content	9–12/Earth and Space Science
Lesson Summary	In this lesson, students work with a partner to research evidence of how stars produce elements during their life cycles. Each pair will present their findings in a digital presentation.
Estimated Time	3, 45-minute periods
Materials	computer, Internet access, presentation software, Investigation Plan, journal
Secondary Resources	NASA: Stars Introduction NASA: Space Images National Schools Observatory: Life Cycle of a Star
NGSS Connection	**HS-ESS1-3** Communicate scientific ideas about the way stars, over their life cycles, produce elements.
Learning Objectives	• Students will describe the mass of a star at one life cycle stage. • Students will identify the life cycle stage of a star, including the names of the stages before and after, as appropriate. • Students will describe the process of element formation at a particular life cycle stage of a star.

How do stars produce elements during their life cycles?

Just like humans, stars have life cycles. Stars are born in star-forming nebula, a cloud of molecular gas and dust. As the cloud collapses, the core forms a protostar that evolves into a star. The mass of each star determines what happens next. A star the size of our sun becomes a red giant and then a planetary nebula before turning into a white dwarf. A massive star, on the other hand, becomes a red super giant before exploding as a supernova to become a neutron star or a black hole.

Stars have fascinated humans for generations. In this digital age, however, humans don't need to wait for the sun to go down to see the stars. Space agencies allow anyone with an Internet connection to view images from galaxies in deep space, and those images are updated as new data is gathered. In this investigation, students will research a particular life cycle stage of a star and communicate how stars in that life cycle stage produce elements. Prepare for a visual feast of nuclear reactions!

Investigation is based on the Van Andel Education Institute (VAEI) Instructional Model for Inquiry-Based Science. In all investigations:

Students don't know the "answer" they are supposed to get.

Students play a driving role in determining the process for learning.

Teachers and students construct meaning together by journaling.

Students are working as hard as the teacher.

Part 1

INVESTIGATION SETUP

To collect, process, and present their data, students will need:

- Computer
- Internet access
- Presentation software (Google Slides, Microsoft PowerPoint, Animoto, Prezi, or any other digital tool)
- Investigation Plan
- Journal

Part 2

INVESTIGATION FACILITATION

Question

Introduce the investigation question.

How do stars produce elements during _____stage?

- Have students work in partners for this lesson. Each pair will choose a life cycle stage of a star to investigate.

CURIOSITY

To promote curiosity, show students images of stars, planets, and deep space objects (galaxies, nebula, clusters, etc.) from Hubble Site or Stellarium. Have students begin to ask questions about what they see. Focus in on stars and the different star types. Let them know that they will be working with a partner to investigate how stars produce elements in a particular life cycle stage.

Personal Knowledge

Students capture what they already know about stars and how they produce elements.

- Ask students to share any personal knowledge they have about stars and star life cycles with a group.
- Remind students to write down what they know in their journals.

COLLABORATION

Have groups of 3-4 students conduct an *Alphabet Knowledge*. Each group writes each letter of the alphabet on a large piece of paper. Have them write a word or short phrase that connects to their prior knowledge of stars and the star cycle for each letter of the alphabet.

Secondary Knowledge

Students use secondary sources to brainstorm ideas about their chosen star cycle stage.

- Allow each pair to choose one life cycle stage of a star using the NASA Stars Life Cycle Diagram as a guide.
- Have students use the diagram to brainstorm their ideas about their assigned star life cycle stage. If they have not heard of the life cycle stage assigned, students should make inferences based on the diagram. Have them write their ideas in their journals.

Prediction

Students communicate an expected outcome, based on prior knowledge.

- Re-introduce the investigation question.
- Ask students to write their prediction about their chosen star cycle stage in their journals.
- Student predictions should be worded: *I predict* _____ *because* _____.

Investigation Plan

Students gather information from secondary sources to determine how stars produce elements during a particular life cycle stage.

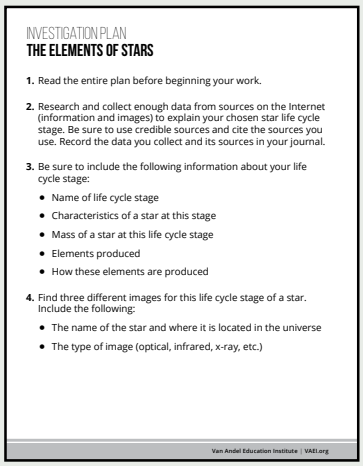
- Students research and collect enough data (information and images) to explain their assigned star life cycle stage with presentation software.
- In addition to any diagrams students use to explain the characteristics of their stage, they should use primary sources to research and save three different telescopic images of their assigned stage. They should include accompanying data (name, location, and image type, such as optical, infrared, or X-ray).
- Remind students to cite their sources as they are gathering information. Discuss with students how to evaluate sources to ensure that information is valid and reliable.

CRITICAL THINKING

Use the Fair Test checklist to help students think critically about the investigation plan. Help them understand that a good investigation plan must include a test that is repeatable, generates quality data, and minimizes error. The more critically students think about their investigation plans, the more confident they can be in their results.

SELF-DIRECTION

As students work in pairs to investigate their assigned star life cycle stage, they will decide how to use their research time. They may research the characteristics, mass, and elements of a star in this stage, and all three images together or split the tasks (information and images) in half.



INVESTIGATION PLAN

THE ELEMENTS OF STARS

1. Read the entire plan before beginning your work.
2. Research and collect enough data from sources on the Internet (information and images) to explain your chosen star life cycle stage. Be sure to use credible sources and cite the sources you use. Record the data you collect and its sources in your journal.
3. Be sure to include the following information about your life cycle stage:
   - Name of life cycle stage
   - Characteristics of a star at this stage
   - Mass of a star at this life cycle stage
   - Elements produced
   - How these elements are produced
4. Find three different images for this life cycle stage of a star. Include the following:
   - The name of the star and where it is located in the universe
   - The type of image (optical, infrared, x-ray, etc.)

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Investigation Plan

Secondary Knowledge

Students use secondary sources to understand how stars produce elements during their life cycle.

Introduce these secondary sources to provide a deeper understanding of the science behind the life cycle of stars.

NASA: Stars Introduction
NASA: Space Images
National Schools' Observatory: Life Cycle of a Star

After reviewing these astronomy websites, students should describe the mass of the star they studied, identify the life cycle stage of a star, including the names of the stages before and after as appropriate, and describe the process the star uses to produce elements at this life cycle stage.

Observation

Students record information about the characteristics of stars and how elements are produced in their chosen life cycle stage.

Have students record their findings in their journals. Encourage them to organize their data in a way that allows them to analyze their data. This analyzed data will be used in their explanation.

Part 3

INVESTIGATION ANALYSIS AND DEVELOPMENT OF CLAIM

Data Analysis

Students make sense of their data by organizing it and representing it visually.

Have students analyze their data. They may wish to use the Data Analysis prompt as a guide.

- Have students **evaluate** their data for trustworthiness. Ask: *Are you confident in the data you collected? How confident are you in the sources you used?*
- Then, have them analyze their data to find patterns and trends. They may **re-organize** the data and/or **represent** it visually to construct meaning.
- Have students **interpret** what the identified patterns or trends mean.
- Ensure they have enough data that it can be used as evidence to support a claim.

Explanation

Students write a claim and provide evidence and reasoning to support it.

- Have students use what they've discovered from their analyzed data to write an explanation that answers their investigation question. Students may wish to use the Explanation prompt as a guide. Have them write their explanation in their journal.
- Have students develop a **Claim** to answer the question: How do stars produce elements during _____stage?
- Then, have them add **Evidence** (the analyzed data) to support their claim.
- Finally, have them add **Reasoning** to their claim. Reasoning should include the information obtained from this investigation as well as science principles they have learned.

Claim

We claim that a star in the supermassive supernova stage produces heavier elements than iron, like uranium and gold, and collapses to create a black hole.

Evidence

Stars have nuclear fusion reactions inside their core. These nuclear reactions release energy as they move out from the core. As a supermassive star converts hydrogen to helium, it releases gamma radiation. When all of the hydrogen has been consumed, the star converts the next heaviest element it has created, moving from helium to carbon and then to oxygen. When only nickel and iron are left inside a star, the nuclear reactions stop.

Continued

While a star is producing nuclear fusion reactions with high temperature and high-speed collisions, it produces pressure that pushes out from the core. At the same time, gravity is pressing downward on the gas of the star. When the nuclear reactions stop pressing outward because only nickel and iron are left inside the star, there is nothing to stop the gravity pressing inward and the star implodes. If the imploding star is a supermassive supernova, the imploding gravity creates a gravity warp in space called a black hole. A supernova explosion releases very large amounts of energy and neutrons. Neutron capture reactions (not nuclear fusion) produce heavier elements than iron, such as uranium and gold. These heavier elements are expelled into space due to the explosion.

Reasoning

Investigation: We followed the investigation plan and used credible resources. We combined data from multiple sources to strengthen our claim.

Science: A black hole is the final stage in the life cycle of a very massive star that is three times the size of our sun. The center of a black hole is called a singularity. Around the singularity, this densely packed gravity point, is an extreme gravity zone. The edge of this zone is called the event horizon. Now that telescopes can capture X-ray images, humans can "see" a black hole by observing what happens at the edge of its event horizon.

A black hole is an infinite gravity warp. The gravity is so strong that it even pulls in light. Black holes grow by pulling in the objects that are near them: gas, dust, and other stars. A large black hole can even pull in a smaller back hole.

In 2016, scientists found evidence that black holes "burp" after they swallow gas, dust, and other stars. An X-ray telescope image of NGC-5195 (in the Messier 51 galaxy system, about 26 million light years from Earth) showed hot X-ray waves pushing two arcs of cool hydrogen gas away from this supermassive black hole. Astronomers think this action may lead to the formation of new stars.

Evaluation

Students reflect on the investigation.

- Ask students what question they would like to investigate next.
- Ask students what surprised them.

Part 4

INVESTIGATION ASSESSMENT AND EXTENSION

Application

Students demonstrate understanding of their chosen star cycle by creating a digital presentation.

- Have students create a digital presentation of their findings to present to the class using Google Slides, Microsoft PowerPoint, Animoto, Prezi, or any other digital tool.
- Have students share their work in a Present and Defend.

Continued

Assessment

- For a **formative assessment**, after the initial research is completed, meet with student pairs and provide guidance as needed. Evaluate their explanations on how well they:
  - describe the mass of a star at one life cycle stage.
  - identify the life cycle stage of a star, including the names of the stages before and after, as appropriate.
  - describe the process the star uses to produce elements at this life cycle stage.
- For a **summative assessment**, evaluate each small group's Present and Defend (digital presentation). Evaluate their explanations on how well they:
  - describe the mass of a star at one life cycle stage.
  - identify the life cycle stage of a star, including the names of the stages before and after, as appropriate.
  - describe the process the star uses to produce elements at this life cycle stage.

Extension

- Have students apply what they know about star life cycles to classify different types of stars by temperature and brightness.
- Give students an opportunity to investigate the relationship between the life cycles of stars, light, and the electromagnetic spectrum.
- For further study, students can investigate brown dwarves, stars that are larger than planets, but not large enough to have a nuclear fusion reaction (nucleosynthesis) in their cores. Divide the class into four small groups, one for each light spectrum: M-class, L-class, T-class, and Y-class.

DISCOURSE

Have students conduct a Present and Defend to develop presentation skills as well as audience participation. Research partners present a summary of their investigation to the class. The class analyzes the information presented and asks clarifying questions, challenges and/or supports the arguments made, and even presents alternative explanations as appropriate. Research teams defend their explanation with evidence and reasoning.

Secondary Knowledge

Students use secondary sources to gain a deeper understanding.

After students finish their presentations, share what you know about the life cycle of a star. Help students see the full picture of the relationship between mass, the elements a star produces, and its eventual outcome. This information can come from videos, websites, or texts.

ADAPTABILITY

Use this secondary knowledge if students need assistance developing a more complete picture of the star cycle and how the mass of the star determines what types of elements are produced.

For additional lessons or to customize this lesson, go to www.nexgeninquiry.org.

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INVESTIGATION PLAN

THE ELEMENTS OF STARS

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3. Be sure to include the following information about your life cycle stage:
   - Name of life cycle stage
   - Characteristics of a star at this stage
   - Mass of a star at this life cycle stage
   - Elements produced
   - How these elements are produced

4. Find three different images for this life cycle stage of a star. Include the following:
   - The name of the star and where it is located in the universe
   - The type of image (optical, infrared, x-ray, etc.)