Grade Level: 9-12

Overview	**Students will create an understanding of how a star evolves, by researching information and organizing it into an outline using Zotero.**
Objectives	Students will understand the following:
1.	Since we cannot watch a star evolve through its entire lifetime, astronomers use their knowledge of a star's behavior at various stages of its life to piece together a picture of the star's entire life.
2.	The most important factor in how a star evolves and eventually dies is its initial mass. (It is assumed that the students already possess background information concerning how stars of different masses evolve---solar mass stars, such as the sun; low-mass stars 0.8 or less than the sun's mass; and higher-mass stars.)
Materials	Only research materials are required for this activity. You might want to have a selection of sources on hand in the classroom, but students should go to the library or the Internet for additional research.
•	Reference materials on stellar evolution, including, if possible, examples of images taken by the Hubble space telescope of stars in different stages of development
•	A computer with Internet access
Procedures	**1.** Ask your students how they think astronomers can make inferences about the life of a particular star, from its birth to its death, taking into consideration that it is impossible to observe a star's evolution through its entire lifetime.
2.	Make sure students understand that because a star's initial mass largely determines how the star will behave at various stages of its life, observing a star at any of those stages can give astronomers information about the star's initial

	mass and, therefore, about how the star was born, will evolve, and will die.
3.	Tell the class that they will be dividing into teams to do research on a star's life. Each team will focus on one aspect of the stellar evolution of a particular star.
4.	Assign each of seven teams a star at a particular stage of stellar evolution: protostar (example: the Eagle Nebula, a stellar nursery), protoplanetary disk and stellar system in formation (example: Orion Nebula), cluster of young stars (example: the Pleiades), middle-aged, normal star (example: the sun), cluster of older stars--~~red giant (example: Betelgeuse), dying stage-supernova, planetary nebula, white dwarf (example: Supernova 1987A), end state of a star~~--black dwarf, black hole, neutron star (example: Cygnus X-1).
5.	Tell students to keep track of the sources for their facts so that they or other interested classmates can go back to those sources for further information.
6.	Encourage students to include visuals in their reports.
7.	Have teams report their findings to the class through a poster session, sharing of photographic or printed sources, PowerPoint presentation, or some other format of the students' own choosing.
8.	After each team's report, have team members lead a whole-class discussion on what could be inferred about earlier and later stages of the star's development based on information about the star at the stage of stellar evolution the team has researched. What can they infer about the star's initial mass? (For example, our sun will never become a black hole because it has too little mass, and therefore too little gravity. Rather, it will expel a ring of gas rich in heavier elements as a planetary nebula and then contract to become a white dwarf.)
Evaluation	You can evaluate your students on their reports using the following three-point rubric:

	• *Three points:*report well researched; information clearly and logically organized; presentation interesting and lively; discussion session well organized • *Two points:*report adequately researched; information sufficiently organized; presentation dull; discussion session disorganized • *One point:*report insufficiently researched; information inadequately organized; presentation poorly prepared; discussion session disorganized You can ask your students to contribute to the assessment rubric by determining a minimum number of facts to be presented in a report and setting up criteria for an interesting and lively presentation.
Standards	This lesson plan may be used to address the academic standards listed below. These standards are drawn from Content Knowledge: A Compendium of Standards and Benchmarks for K-12 Education: 2nd Edition and have been provided courtesy of theMid-continent Research for Education and Learning in Aurora, Colorado. *Grade level:*6-8 *Subject area:*space science **Standard:** Understands essential ideas about the composition and structure of the universe and the Earth's place in it. **Benchmarks:** Knows that the sun is the principle energy source for phenomena on the Earth's surface (e.g., winds, ocean currents, the water cycle, plant growth).Knows characteristics and movement patterns of the nine planets in our solar system (e.g., planets differ in size, composition, and surface features; planets move around the sun in elliptical orbits; some planets have moons, rings of particles, and other satellites orbiting them). Knows that the planet Earth and our solar system appear to be somewhat unique, although similar systems might yet be discovered in the universe. Knows characteristics and movement patterns of asteroids, comets, and meteors. *Grade level:*9-12 *Subject area:*Earth science **Standard:**

	Understands basic features of the Earth. **Benchmarks:** Knows how life is adapted to conditions on the Earth (e.g., force of gravity that enables the planet to retain an adequate atmosphere, intensity of radiation from the sun that allows water to cycle between liquid and vapor). *Grade level:*9-12 *Subject area:*space science **Standard:** Understands essential ideas about the composition and structure of the universe and the Earth's place in it. **Benchmarks:** Knows the ongoing processes involved in star formation and destruction (e.g., stars condense by gravity out of clouds of molecules of the lightest elements; nuclear fusion of light elements into heavier ones occurs in the stars' extremely hot, dense cores, releasing great amounts of energy; some stars eventually explode, producing clouds of material from which new stars and planets condense). Knows common characteristics of stars in the universe (e.g., types of stars include red and blue giants, white dwarfs, neutron stars, and black holes; stars differ in size, temperature, and age, but they all appear to be made up of the same elements and to behave according to the same principles; most stars exist in systems of two or more stars orbiting around a common point). Knows ways in which technology has increased our understanding of the universe (e.g., visual, radio, and x-ray telescopes collect information about the universe from electromagnetic waves; computers interpret vast amounts of data from space; space probes gather information from distant parts of the solar system; accelerators allow us to simulate conditions in the stars and in the early history of the universe). *Grade level:*9-12 *Subject area:*physical science **Standard:** Understands energy types, sources, and conversions, and their relationship to heat and temperature. **Benchmarks:** Knows that nuclear reactions convert a fraction of the mass of interacting particles into energy (fission involves the splitting of a large nucleus into smaller pieces; fusion is the joining of two nuclei at extremely high temperature and pressure) and release much greater amounts of energy than atomic interactions.

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