

STELLAR ASTRONOMY FOR HIGH SCHOOL EARTH SCIENCE STUDENTS: TEACHING BY USING ANALOGIES

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Introduction

High school students are required to understand the development stages of stars, the evolution of stars, and the processes occurring in stars. Stars and stellar evolution are abstract concepts which can be difficult to teach. Work has demonstrated analogical thinking and the implementation of analogies are powerful tools in teaching.

Background

- Ninety percent of all stars comprise what is known as the Main Sequence on the Hertzsprung-Russell (H-R) Diagram. The Main Sequence stars form a diagonal band across the H-R Diagram.
- The mass of a star is the largest determining factor in its lifespan.
- Low mass stars burn fuel very slowly, thus providing them with a long lifespan on the Main Sequence.
- High mass stars burn fuel very quickly, thus providing them with a short lifespan on the Main Sequence.
- The relationship between cars and gas mileage is analogous to stars and life expectancy (Figure 1 & Figure 2).

Analogy: Stars as Cars, Part I – Small Stars

A low-mass star is like a small fuel-efficient economy car:
Small fuel tank
Low power engine (low energy output)
Excellent "gas mileage"
Consumes its fuel very slowly



Result:
Low-Mass stars stay on the Main Sequence for a very long time.

Figure 1: How low-mass stars are analogous to economy cars. From POGGE. Lecture Notes Graphic from The Ohio State University, Department of Astronomy. Reproduced by permission.

Stars as Cars, Part II – Big Cars

A high-mass star is like a Hummer:
Large fuel tank
High-Power engine (high energy output)
Low "gas mileage"
Consumes its fuel very quickly



Result:
High-Mass stars run out of fuel and leave the Main Sequence after a very short time.

Figure 2: How high-mass stars are analogous to trucks. From POGGE. Lecture Notes Graphic from The Ohio State University, Department of Astronomy. Reproduced by permission.

- The life cycle of a Main Sequence star is similar to a human's life cycle, both are born, live a finite life, and eventually die (Figure 3).
- The Main Sequence of Stars is analogous to the Main Sequence of Cars (Figure 4).

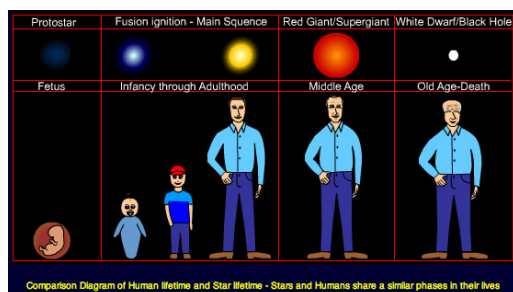


Figure 3: The life cycle of stars is analogous to that of humans. From CALLAHAN. Internet Graphic from the University of Utah, Department of Physics & Astronomy. Reproduced by permission.

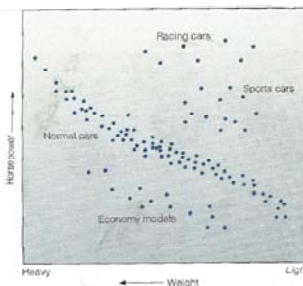


Figure 4: An imaginary H-R Diagram for cars is analogous to the H-R Diagram for stars. From SEEDS. *Horizons: Exploring the Universe*, 4E. © 1995 Brooks/Cole, a part of Cengage Learning, Inc. Reproduced by permission.

Procedure

This study was conducted to determine if it was feasible to utilize analogical thinking to teach high school earth science students about stars and stellar evolution. Approximately 135 junior and senior earth science students at the Miami Valley Career Technology Center in Clayton, Ohio were taught about stars and stellar evolution by lecture featuring a H-R Diagram. During direct instruction, a total of three analogies were used: 1. The fuel consumption of massive stars is similar to that of large cars, 2. Stars have a lifecycle like humans with a beginning and end, and 3. The H-R Diagram of stars is analogous to an imaginary H-R Diagram of Cars where the relationship between surface temperature and magnitude in stars is similar to the relationship between weight and horsepower in cars. At the conclusion of the lesson, all students were administered a quick write prompt ("How are stars like cars and people?") in order to determine the effectiveness of these analogies for understanding stars and stellar evolution.

Results

Stars are like cars because they have fuel tanks and engines.
Stars along the Main Sequence are like the cars on the highway.
Stars with high mass are like Hummers.
The Main Sequence stars have low gas mileage, like other cars.
Stars with low mass are like economy cars.
Stars with high mass are like Hummers.
Stars are like people, because they live and die.
For example, a star is born through a process, and humans are born through a process.
Humans go through stages in life, like stars.
Stars go through stages in their life cycle, and both humans and stars eventually die.

Stars are like cars.
For example, take a car with one gas tank and take a car with two gas tanks. Then send them down the highway as fast as they can go. The car with one gas tank will stop before the car with two gas tanks, because the car with one gas tank will run out of energy.
First, just like stars.
Stars are like people, because they live and die. For example, a star is born through a process, and humans are born through a process.
Humans go through stages in life, like stars.
Stars go through stages in their life cycle, and both humans and stars eventually die.

Stars are like cars.
Stars are like cars in which some cars weigh more than others. Like how some stars are bigger than others. Not only do some stars have different sizes but they also have different rates of burning their energy just like some cars burn less gas while others burn more gas. Most larger cars burn gas faster just like larger stars. While smaller cars typically burn less fuel similar to smaller stars.

Figures 5, 6, and 7: Collins quickwrite responses submitted by three students.

Conclusions

Quick write prompts suggested that the analogies were useful in helping students to understand general principles of stars and stellar evolution. However, the analogies may have had limitations in helping students to understand core concepts such as how the mass of a star influences stellar evolution. Future research studies may help to determine the best methods and techniques of implementing analogies to teach about stars and stellar evolution. Additional studies will investigate the integration of technology such as stellar evolution software in conjunction with analogical thinking and whether both will enable students to fully grasp the development stages of stars, the evolution of stars, and the processes occurring in stars.

References

- Glynn, S.M. (1991). Explaining science concepts: A Teaching-with-analogies Model. In S.M. Glynn, R.H. Yeany, & B.K. Britton (Eds.), *The Psychology of Learning Science* 9pp. 219-240).
- Jee, B.D., Uttal, D.H., Gentner, D., Manduca, C., Shipley, T.F., Basil, T., Ormand, C.J., and Sageman, B. (2010). Commentary: Analogical Thinking in Geoscience Education. *Journal of Geoscience Education*, V. 58, n. 1, 2-13.
- Internet Resource. (2011). http://www.astronomy.ohio-state.edu/~pogge/Ast141/Unit5/Lect32_Lives.pdf
- Internet Resource. (2011). <http://aspire.cosmic-ray.org>
- Locker, L. (2011). Personal Communication, Sinclair Community College Department of Physics, Dayton, Ohio.
- Pogge, R.W. (2011). Personal Communication, The Ohio State University Department of Astronomy, Columbus, Ohio
- Seeds, M.A. (2011). Personal Communication, Franklin & Marshall College, Lancaster, PA.
- Seeds, M.A. (1998). *Horizons: Exploring the Universe*. New York, NY: Wadsworth Publishing Company.