

UNIVERSE FORUM ASSESSMENT PROJECT
STANDARDS BREAKDOWN
Origin and Evolution of the Universe

The following document is based on statements from the NRC's National Science Education Standards, and from the AAAS Benchmarks, regarding what students should know about the origin and evolution of the universe by the end of 12th grade. Here, we break these more complex narrative ideas down into component concepts, many of which are frequent sources of student misconceptions. Our Space Science Assessment Project uses these component concepts to inform the development of appropriate assessment instruments.

9–12 STANDARD I: THE ORIGIN AND EVOLUTION OF THE UNIVERSE

A. Stated Concept: “The origin of the universe remains one of the greatest questions in science. The "big bang" theory places the origin between 10 and 20 billion years ago, when the universe began in a hot dense state; according to this theory, the universe has been expanding ever since.”

1. Component Concept: The universe is very old.
 - a. The universe is older than the earth.
 - i. the earth (and the sun) were not formed as part of the “big bang”
 - b. The universe is between 10 and 20 billion years old.
 - i. the best current estimate for the age of the universe is 13.7 billion years
2. Component Concept: The universe began as being very hot and has cooled with time.
3. Component Concept: The universe began as being very dense and has gotten less dense with time.
 - a. Galaxies are getting farther apart.

9–12 STANDARD I: THE ORIGIN AND EVOLUTION OF THE UNIVERSE

B. Stated Concept: “Early in the history of the universe, matter, primarily the light atoms hydrogen and helium, clumped together by gravitational attraction to form countless trillions of stars. Billions of galaxies, each of which is a gravitationally bound cluster of billions of stars, now form most of the visible mass in the universe.”

4. Component Concept: The universe began as being very uniform and has gotten more “lumpy” with time.
 - i. matter was not instantly formed by the “big bang”
5. Component Concept: The first matter formed in the universe was hydrogen and helium.
 - b. All other elements were formed after hydrogen and helium.
6. Component Concept: The universe's visible matter exists mostly of stars.
 - i. stars are bound together gravitationally into very large clusters called galaxies, which are also visible
 - i. there are billions of stars in a galaxy
 - ii. there are billions of galaxies in the visible universe

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9–12 STANDARD II: THE PHYSICAL SETTING

- B. Stated Concept:** “On the basis of scientific evidence, the universe is estimated to be over ten billion years old. The current theory is that its entire contents expanded explosively from a hot, dense, chaotic mass. Stars condensed by gravity out of clouds of molecules of the lightest elements until nuclear fusion of the light elements into heavier ones began to occur. Fusion released great amounts of energy over millions of years.”
7. Component Concept: The fusion of hydrogen and helium was necessary for the formation of other elements.
- c. This fusion process occurred inside stars.
 - d. Some stars had to explode to release the heavy elements into space.
 - e. Fusion has released great amounts of energy over time.

9–12 STANDARD II: THE PHYSICAL SETTING

- C. Stated Concept:** “Eventually, some stars exploded, producing clouds of heavy elements from which other stars and planets could later condense. The process of star formation and destruction continues.”
8. Component Concept: Star formation is an ongoing process.
- f. Stars are constantly being formed, grow old and die.
 - i. astronomers use terms such as birth, aging and death to describe various stages in the existence of a star
 - ii. stars are not “immortal”
9. Component Concept: The cycle of star formation and death is important to the formation of other objects.
- a. Newer stars, like the sun, plus planets, moons, asteroids, and comets are made from material that originally formed inside stars or by the explosion of stars.
 - i. most of the matter we observe, on earth or in outer space, was not formed in the “big bang”

9–12 STANDARD III: UNDERSTANDING THE UNIVERSE

- A. Stated Concept:** “Increasingly sophisticated technology is used to learn about the universe. Visual, radio, and x-ray telescopes collect information from across the entire spectrum of electromagnetic waves; computers handle an avalanche of data and increasingly complicated computations to interpret them; space probes send back data and materials from the remote parts of the solar system; and accelerators give subatomic particles energies that simulate conditions in the stars and in the early history of the universe before stars formed. Mathematical models and computer simulations are used in studying evidence from many sources in order to form a scientific account of the universe.”
10. Component Concept: We learn about the universe by using technology to collect information.

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- g. We collect physical samples from objects in our solar system.
 - i. astronauts have brought rocks back from the moon
 - ii. space probes collect samples from objects and return them to earth
 - iii. scientists collect rocks on earth that came from other places in our solar system
 - h. We collect electromagnetic waves emitted or scattered by objects.
 - iii. collectors vary by type of wave that they can detect: radio, microwave, infrared, visible, ultraviolet, x-ray, gamma ray
 - iv. collectors vary by location: on earth, earth orbit, sun orbit, solar system object fly-bys, solar system object orbit, solar system object landings
 - v. all electromagnetic waves, including visible light, share some common properties
11. Component Concept: We use equipment on earth to help us make sense of the universe.
- a. We perform laboratory experiments.
 - i. experiments can replicate phenomena we observe to allow detailed study
 - ii. experiments can test ideas about phenomena
 - iii. experiments on earth obey the same natural laws as exist throughout the observable universe
 - b. We use computers to manipulate data.
 - i. computers are necessary to sort and compile the huge amounts of information about the universe that we collect
 - ii. computers are needed to run mathematical models that simulate how we think certain phenomena behave