

THE SOLAR SYSTEM IN ITS UNIVERSAL CONTEXT: IDEAS, MISCONCEPTIONS, STRATEGIES, AND PROGRAMS TO ENHANCE LEARNING. J.A. Grier, E.L. Reinfeld, M.E. Dussault, S.J. Steel and R.Gould¹, ¹Universe Forum, Harvard-Smithsonian Center for Astrophysics, 60 Garden Street, Cambridge, MA 02138, jagrier@cfa.harvard.edu, <http://cfa-www.harvard.edu/seuforum/>

Summary: The Universe Forum conducts a variety of education programs in formal, informal and community venues, giving us an opportunity to collect a wide range of data regarding student and teacher ideas about the universe. We will present the preliminary analysis of our data relevant to learning about the solar system, particularly relating to its place within the context of the larger universe. Data have been collected from surveys, interviews, modeling activities, specifically tailored multiple-choice assessments and other forms of evaluation.

Our data suggest that some of the misconceptions relating to the size of the solar system, placement, distance, scale and hierarchy of astronomical objects are introduced or reinforced by not including the solar system in a consistent, coherent picture within the rest of the galaxy and universe. If these ideas and misconceptions are not addressed, they can form barriers to developing new and more accurate internal models, and impede the assimilation of any new evidence or ideas within those models.

We are developing focused educational products and experiences, as well as investigating appropriate strategies, that allow students to encounter topics in space science as an integrated whole, showing the common and unique features, natural inter-relationships, and hierarchies that allow students and teachers to develop more powerful internal models of their place in space and time.

Data: We will present a preliminary look at what students and teachers think the relationships are between the ideas of 'solar system', 'galaxy', and 'universe', and how those ideas impact learning. Our data include categorized answers to survey and interview questions. Examples include:

When students were asked what the word 'universe' made them think of, the content of their responses could be categorized as follows (responses may fall into multiple categories);

1. Solar System only.
2. Solar System with other stars sprinkled throughout the system.
3. 1 and 2, but with some mention or indication of the Milky Way
4. Milky Way galaxy only (often showing the location of the solar system and other objects, such as a black hole)
5. Multiple galaxies

6. Multiple galaxies with stars sprinkled randomly throughout
7. Galaxies, planets and stars represented randomly scattered together, or shown with some indication of proper relationships
8. As in 5 to 7, but with some indication of the edge or boundary of space, or a depiction of an expanding/contracting space or universe
9. Existential responses ('where everything happens,' 'place of wonder').

The middle school students had more answers in the lower numbers above, and the high school students had more answers in the higher numbers, but the general categories were ALL represented. One exception is the 'existential' category above, which is more likely to be found from middle school students.

When students were asked to describe a galaxy, the content of their responses could be categorized as follows (responses may fall into multiple categories);

1. The Solar System (i.e. the Sun or a single star and planets going around it, often with orbits depicted.)
2. A disorganized collection of stars and planets, often mentioning 'lots of space' or 'dark space'
3. A collection of stars and planets arranged in a spiral.
4. As in 3, but with mention that there are three kinds of galaxies
5. As in 1-3, but may include mention of other forces, such as gravity, or other contents, such as light and color, and other aspects, such as size ('really big')
6. Same as the description for 'universe'
7. Existential responses ('mysterious')

Middle school students most often described a galaxy as 1, just the Solar System, but also 2. They also commonly described it almost exactly as they did the 'universe', category 6. High school students were more likely to describe it as a spiral, or one of many, or to include other concepts as in category five. But ALL answers were still represented in the high school groups. Many high school students clearly still confuse 'galaxy' with 'solar system' and also with 'universe'. Most middle school students surveyed showed some confusion with all three.

Ideas and Misconceptions: From our data we have identified several major ideas and

misconceptions relating to the solar system in its universal context:

1. Confusion between 'solar system', 'galaxy' and 'universe'.
2. Confusion between 'planet', 'star', and 'galaxy'.
3. Confusion over the location of stars, planets, and galaxies with respect to one another
 - a. An idea that Pluto is further than the stars, and is the furthest object in the universe
 - b. An idea that the planets are always in a line, or move on actual tracks in space
 - c. Stars are sprinkled between the galaxies
 - d. If the solar system is depicted within the Milky Way, it is most often shown at or near the center of the galaxy. The Sun is often at the immediate center.
4. Overall lack of relative or absolute concept of size, scale and distance within and between the solar system, the galaxy and the universe.
5. Overall lack of understanding of causality and change with time; what formed the planets, what formed the galaxies, what formed the universe, and how these things evolve.
6. An idea that spacecraft have gone well outside the solar system, to other stars/planets, and even out of the galaxy completely.

Results and Analysis: Where do we believe these major ideas and misconceptions come from? The apparent confusion between 'solar system', 'galaxy' and 'universe' can arise either from simple confusion of terminology, or actual confusion between what the objects are. For some, these words represent the same general idea of a very large-scale astronomical structure or system, and there is no other sense of interrelationships. Similar confusion arises over 'planet,' 'star,' and 'galaxy'. Some students have heard that 'Jupiter is a failed star'. Venus is often referred to as the 'evening' or 'morning star' and all planets have the same general appearance in the night sky.

A number of misconceptions appear to arise from the fact that middle school tends to focus on the solar system, and does not go further into the galaxy or universe. Stopping at the edge of the solar system reinforces the idea that the solar system is all there is, and the galaxy and the universe must be the same thing. Pluto must be the farthest thing in the universe. This may also be a contributing factor in

depicting the sun or solar system at the center of the galaxy.

Misconceptions are of course generated from popular culture, such as seeing imagery without proper context or explanation. Images, movies and animations are presented without any suggestion of what represents 'reality' and what is exaggerated or fabricated.

Strategies: How can these ideas and misconceptions be addressed so they do not impede further learning about the solar system and larger universe? Our poster will discuss details about the following suggested strategies:

1. Know the major misconceptions and be prepared to address them directly.
2. Elicit student/learner ideas up front.
3. Present content about the solar system within the context of the galaxy and larger universe.
4. Discuss evidence and explanation.
5. Give students the opportunity to find themselves within the larger cosmos.
6. Directly address the concept of models, both scientific models, and the development and evolution of internal models.

Activities, Products and Programs: In conjunction with our missions and other partners, the Universe Forum has developed focused educational products and experiences that allow students and teachers to encounter the topics mentioned here as an integrated whole, showing the common and unique features, natural interrelationships, and hierarchies that allow them to develop more powerful internal models of their place in space and time. Our poster will present details of the products and experiences that we have found effective.

We have used this approach to enhance the learning experience for trainers with the Girl Scouts of the USA, with teachers in the 'Modeling the Universe' Professional development workshops, an in several venues for urban public school teachers. We have also created activities such as the 'Cosmic Timeline' and products such as the 'How Big is the Universe?' booklet to support learning about size and scale from the Earth to the Sun, and then all the way out to the edge of space.

To Learn More: The activities, products and ongoing programs mentioned here can be found at:

<http://cfa-www.harvard.edu/seuforum/>