DETERMINGING AGE: AN EDUCATIONAL PERSPECTIVE ON OUR PLACE IN TIME. J. A. Grier, S. J. Steel, M. E. Dussault, and R. R. Gould. Harvard-Smithsonian Center for Astrophysics, Science Education Department, Structure and Evolution of the Universe Forum, 60 Garden Street, MS71, Cambridge, MA, 02138.

Summary: We will present a poster detailing our development of a content strand called "Our Place in Time". We hope to use this opportunity to introduce our current ideas for the strand, as well as to generate discussion and acquire feedback from interested scientists and educators. This strand integrates a continuum of ideas, and will be a natural focus point for interaction and collaboration with scientists and educators in solar system exploration and beyond. Eventually, the resources developed in conjunction with this strand will be useful to those educating students from K-16 and graduate students. Scientists interested in making their work more easily accessible to the media and general public will find the strand helpful in providing a big-picture context for their research.

Introduction: We are developing an educational content strand called "Our Place in Time" which is keyed to the questions "How old is something?" and "How do you find out?" This subject matter is inherently cross-thematic, naturally touching on and requiring integration of ideas from the Humanities, Earth Science, Solar System Exploration, and the frontiers of Cosmology. These questions are asked by scientists, students, teachers and the general public alike, and so have universal appeal. The questions range from basic ones ("How old am I? How old is my school? My state?"), to more complex questions ("How old is that tree? What is the oldest civilization?"), to quite advanced ("When was the Earth formed? How old is the galaxy? When did the universe begin?")

In every case, the question that follows is "How do I know that?" or "How do I find out?" While the techniques, tools, and data used to determine age may vary depending on the question, the critical thinking process is the same. The same way a scientist approaches the question is also the way a student in an inquiry-based science environment will be led to approach it.

We plan to develop resources supporting this content strand, such as a website, activities, and handouts. These can be designed with applicability to formal K-12 learning through undergraduate education. Such resources will also provide a framework that will allow graduate students and active scientists to present their research to a wider audience (media, general public, reports, etc.) in a more accessible fashion.

Details: The strand consists of a list of questions centered on specific topics, and the means whereby we attempt to answer these questions. The examples here are chosen to show the range of possible questions, subject matter and the types of cultural and scientific approaches used. The strand is built to create connections from a person's direct experience (what they can touch and what is of a small understandable age), to a long chain of items further removed from the person, and of progressively larger age. This offers a sense of place as we move back through time - as ages become so large it is otherwise difficult to obtain any perspective or *sense of relevance*. A connected chain of ages and techniques allows for perspective and a sense of relevance to develop in the mind naturally, leading to answering the overarching question "What is our place in time?" Topic examples for parts of the chain:

<u>Topic: My Own Age</u>

Questions: How old am I? How do I know?

Techniques: We have a personal memory of our age, and can recall how many seasons we have seen, or birthday parties we have had. But what if you woke up and did not remember any of these, how would you find out your age? Possibilities include using your understanding of human biology - that people grow, change and have life cycles - to estimate your age by looking in a mirror. You could check on "observational" data, i.e. eye-witness accounts from your family and friends. Using your knowledge of your culture, that we are in a society that requires and keeps records, you could look at your birth certificate, driver's license, etc.

<u>Topic: The Age of Artifacts</u>

Questions: How old is this table? When was this pottery created? How do I find out?

Techniques: Specific styles and patterns of human artifacts have been studied in detail, and cultural anthropologists can use this information to constrain the ages of manufactured items. It might be known how pottery styles changed over time, so one can tell which pot is older than another. Or the dovetail construction of the legs on a table may only have been used after 1600. Like most techniques, these do not provide a specific age, but instead allow the pots to be compared in age to one another, or determine the minimum age for the table.

<u>Topic: The Age of Trees</u>

Questions: How old is this tree? How old is this piece of wood, or wooden artifact?

Techniques: The age of a tree recently felled or otherwise can be determined through tree ring dating. Particular rings can sometimes be tied to fires, changes in climate, etc. Very old wood or wooden artifacts can have their ages constrained through carbon dating techniques.

Topic: The Age of Humanity

Questions: How long have humans been on Earth? How do I find out?

Techniques: Remnants or fossils of suspected ancient humans have been found in different rocks. The age of a sedimentary rock holding ancient human fossils might be determined from tracking the magnetic pole reversal information held in the rock, i.e. paleomagnetism. Other ancient fossils found trapped in lava flows have had their ages constrained by doing Ar-Ar dating on the lava rock.

Topic: The Age of the Solar System

Questions: How old are planetary surfaces, such as the lava flows we see on Mars? How old are the planets and asteroids themselves? Do they all have the same age? How about the Moon? How do I find out?

Techniques: Radiometric dating techniques such as Rb-Sr, and U-Pb, are useful for finding the ages of some very old rocks, such as ancient lunar rock samples, and even more ancient meteorites. When samples of rock are not available for radiometric or sample analysis techniques of finding age, then remote sensing techniques must be used. One possibility is to count the number of craters on one lava flow versus another, to get the relative ages of the flows. Older flows have theoretically had more time to collect craters than younger flows. All these ages, along with chemical data and models of planet origins and evolution are integrated into a coherent picture for the timing of the formation bodies in the solar system.

Topic: The Ages of Stars

Questions: How old are the stars? Are they all the same age? How about the age of a star cluster?

Techniques: The age of a star can be determined by knowing both its mass, composition and luminosity. The energy output (from theories of fusion reactions) over luminosity gives an expected lifetime. The HR diagram, created by plotting the temperature versus the luminosity of stars, shows the pattern of stellar evolution. Assuming we then understand how a star's position on the diagram changes with time, then the age of an entire cluster of stars can be determined without knowing the mass by plotting their positions on the diagram. This is an excellent illustration of how a powerful tool, model, or theory can extend our ability to answer questions.

Topic: The Age of the Universe

Questions: How old is the universe? Did the universe begin at a specific point in time?

Techniques: Using redshifts, we can determine how fast the galaxies are moving away from us, with closer galaxies moving at a different rate than the ones very far away. This is keyed to the concept that as you look far away into the universe, you are actually looking back in time because the speed of light is finite. If you know the expansion rate of the universe, you can then work backwards to determine when the observable universe was packed into an area smaller than a grapefruit.

Interactives and Handouts: Additionally, we plan to showcase interactives and other materials associated with recent projects and SEU missions. We plan to offer some handouts for educators and others that were developed in conjunction with the Cosmic Questions Exhibit. This is large (5000 sq. ft) exhibit developed in partnership with the Smithsonian, NASA, and NSF. The exhibit guides visitors through some of the oldest and most far-reaching questions of our place in the universe. It began its national tour at the Boston Museum of Science, and will continue to tour the country for 3+ years. Handouts and CDROMS from SEU theme missions, such as images from the Chandra Spacecraft, will also be available at our poster.