HANDS-ON ACTIVITIES FOR INTRODUCTORY COLLEGE LEVEL ASTRONOMY CLASSES. S. K. Croft, Department of Science, Pima Community College, Downtown Campus, 1255 N. Stone Ave., Tucson AZ 85709 (skcroft@pima.edu).

Introduction: Introductory astronomy classes in community and four-year colleges are often the last contact students will have with formal science education. In order to help these students become scientifically literate citizens with positive attitudes towards the enterprise of science in the national community, it is imperative that these science classes are as engaging and interactive as possible. One of the best ways to do this is through hands-on activities that involve the students in the data and process of science [1]. At Pima Community College, three separate introductory semester-long astronomy courses are taught: 1) Solar System 2) Stars, Galaxies and Universe, and 3) Life in the Universe. These classes are integrated lecture-lab courses, which provide the opportunity to transition directly from classroom discussions to lab activities and back. Over the last several years, a number of new hands-on labs and activities have been developed to replace the more traditional paper/pencil activities. Many of our activities are specific to the equipment available at Pima College, but several are useable in more general situations. The computer portions of the following activities are done using a free image processing application called ImageJ available from the National Institute of Health, although any comparable image processing application would suffice. Here is a sampling of our new activities:

Solar System:

Archaeoastronomy. This activity provides oriented satellite images of major archaeological sites from around the world such as the Great Pyramids of Egypt and Uaxactun, Guatemala. In class, we discuss determination of the cardinal points and solstice sun-rise and sunset directions and how archaeological structures are often aligned with these points on the local horizon. Students then explore the images – hard copy or online - for possible alignments. A classroom discussion of individual's results follows directly afterwards.

Mars Resolution. This activity features a series of images of the Cydonia region of Mars at resolutions ranging from 11.7 km/pixel (Hubble image) to 2 m/pixel (MOC image), including the 50 m/pixel Viking image of the "Face on Mars." Students are asked to interpret what they see and the validity of their observations at each resolution step." There is a follow-up discussion (usually vigorous) of the images after the students have completed their own exploration. The activity illustrates the meaning and value of resolution in astronomical images, and why we send spacecraft to other places in the Solar System rather than just rely on telescopic observations.

Stars, Galaxies and Universe:

Mathematical Models & Interior of the Sun. Mathematical models of complex structures, such as the interior of the Sun and other stars are among the most difficult concepts to make "real" to non-science majors. Here we build a stack of bricks one at a time on an ordinary bathroom weight scale to develop a simple linear equation that can be used to calculate the pressure at any point in the stack and to predict the pressure at any point in a stack with an arbitrary number of bricks. We discuss the role of density and compression using a stack of foam bricks to illustrate how the equation can be changed to accommodate a number of variables. This activity is followed by a discussion of stellar interior models.

Stellar Remnants. This is a largely computer-based activity utilizing images of several planetary nebulae and supernovae to measure expansion velocities and the nature of the remnant in each case. Students then compare the general characteristics of each type of remnant.

Center of the Galaxy, 3-D. This is a variation on the oft-done determination of the center of the Milky Way Galaxy using Harlow Shapley's globular cluster position-distance data. The variation here is to use the data to create a 3-D model of the clusters out of a Styrofoam block, plastic beads and wooden skewers (cheap). The 3-D model helps the student better visualize the shape of the galaxy than the usual 2-D graphs.

Galaxy Collisions. This activity is a combination computer analysis and physical simulation of the frequency of collisions in a small cluster of galaxies (the Local Group), a medium-size cluster, and a dense cluster. The images are used to estimate the size, number density of galaxies and the frequency of galaxy collisions in each cluster type using a simple mathematical model. A physical simulation of each cluster type is then made in the classroom using stapled paper plates as the scaled galaxies. Students then toss the paper plates through the classroom and count collisions for each type. The results from the images and the physical collisions are then compared.

Life in the Universe:

Energy for Life. This activity utilizes simple spinning radiometers to estimate light intensity and energy available for life processes as a function of distance from a light source like the Sun. The variation of light intensity with latitude on Earth is also estimated using the radiometers and compared with the density of vegetation on the surface of Earth.

Tree of Life/Fossils. This is a three-part activity comparing living members of the main phyla on the Tree of Life with examples of fossils from the same phyla. The first part is an online search for images of typical members of phyla on a standard taxonomic tree (the one I use is by the National Biological Information Infrastructure, though any comparable tree would suffice); part 2 is a visit to a biology lab or zoo, or natural setting to find more example of living organisms over a range of phyla, and part 3 is a comparison of a suitable collection of fossils to compare differences between the living and extinct members of the same phyla as a function of age. The comparison necessarily crude since this is an astrobiology class, but gets across the idea of evolutionary changes over time as well as giving students experience with fossils and the world around them.

Invitation: These activities have been "classroom tested" a number of times, but they are being continually being as experience shows what works and what doesn't. If you are interested in trying one or more of these activities in your classes, and perhaps making suggestions to improve their educational value, please contact me.

References: [1] National Research Council (1996) *National Science Education Standards*.