TYRANNOSAURUS REX AND STEGOSAURUS NEVER MET: THE IMPORTANCE OF TIME IN ASTROBIOLOGY. L. S. Brock[1], C. D. Impey[2], E. E. Prather[2], and S. R. Buxner[3], [1]Department of Planetary Sciences, University of Arizona, Tucson, AZ 85721, laci@lpl.arizona.edu, [2]Department of Astronomy and Astrophysics, University of Arizona, Tucson, AZ 85721, [3]Department of Teaching, Learning, and Sociocultural Studies, University of Arizona, Tucson, AZ 85721.

Introduction: Astrobiology is unique. As a multidisciplinary venue, it is capable of bringing exciting science to diverse learners through formal, informal, and free-choice learning environments [1, 2, 3]. The field requires collaboration and cooperation of scientists and educators across the disciplines of astronomy, biology, geology, and chemistry. Developing instructional content for such a vast field requires careful consideration and proper instruction to be most effective. Though significant strides have been made over the past several years, the available literature suggests attention related to a key component in astronomy education, and the closely related field of astrobiology, remains absent—time.

Research related to students' knowledge of geological time (i.e., the 4.54 Gyr age of Earth to present day) is well-researched [e.g., 4, 5], whereas research on an understanding of cosmological time (i.e., time stretching even farther back to the 13.8 Gyr age of the Universe) is lacking. In general, it can be observed that students struggle with absolute and relative timescales, over or under estimate large orders of magnitude, think life arose concurrently with Earth's formation, and believe Earth and the Universe formed at the same time. These common confusions among students can have severe implications for learning astrobiology and must be carefully considered when developing astrobiology-related curricula and courses.

Building Temporal Frameworks: Our research has focused on how undergraduate students—both non-science and science major—construct temporal frameworks in the context of Earth's place in the Universe. Our "big idea" approach focuses on placing Earth into the larger cosmic landscape and asking students to consider when Earth formed, how it formed, and what cosmic events led to its formation.

In one of our studies, we asked a sample of 170 undergraduate students enrolled in an ASTRO 101 course to respond to open-ended questions about the aforementioned topics. Responses were iteratively analyzed and thematically coded. Rather than focus on correct responses, we searched for patterns in what was missing, or what knowledge may help students to form a more comprehensive (and scientifically correct) response with their prior knowledge. Students' knowledge of scientifically accurate timescales and the causality between astronomical events was missing. For example, 72% of students responded "no" when asked if "all planets in the Universe formed at the same time" but were unable to explain their reasoning. Other students correctly identified that Earth came after the Big Bang, yet suggested life existed in space prior to arriving on Earth.

Looking Ahead: The success and effectiveness of astrobiology as a venue for conveying complex, interwoven science knowledge is highly dependent upon an ability to appreciate the immense evolutionary timescales involved. Without carefully crafted and targeted instruction on the connections between key aspects of geological and cosmological timescales in astrobiology, students are unlikely to develop scientifically robust ideas with regards to when life began on Earth and how this relates to the search for life elsewhere in the Solar System.

Finding ways to make vast timescales personally meaningful and relevant to students' lives remains challenging, but it is essential. Concepts that stick with learners are arguably more beneficial in introductory courses than thoughtless memorization of facts and quantities. The profound notion that more time passed between *Tyrannosaurus rex* and *Stegosaurus* than time between humans and the extinction of the dinosaurs is only one example of developing macroevolutionary points-of-interest across time.

References:

[1] Fergusson J. et al. (2012) *Astrobiology*, 12, 1143-1153. [2] Oliver C. A. and Fergusson J. (2007) *Acta Astronautica*, 61, 716-723. [3] Barge et al. (2013) *Astrobiology*, 13, 1-6. [4] Catley K. M. and Novick L. R. (2009) *Journal of Research in Science Teaching*, 46, 311-332. [5] Libarkin et al. (2005) *Journal of Geoscience Education*, 53, 17-26.