Content Clarification for Modeling the Universe: Earth and Space Science—Models, Evidence, and Explanation

Vision of Lasting Knowledge and Skills: Related Content Knowledge and Adult Science Literacy statements from SFAA, NSES, Benchmarks	**Grade Level Learning Goals and Inquiry Abilities** (combined Benchmarkes for Science Literacy and National Science Education Standards)	**Ideas about Student Learning** from formal and informal research (compiled from NSES essays, Benchmarks Ch 15, AER, informal education evaluations)	**MTU investigations/activities/resources** **Fill in connections to YOUR curriculum topics/ related content**
A model of something is a simplified imitation of it that we hope can help us understand it better. A model may be a device, a plan, a drawing, an equation, a computer program, or even just a mental image. Whether models are physical, mathematical, or conceptual, their value lies in suggesting how things either do work or might work….When a model does not mimic the phenomenon well, the nature of the discrepancy is a clue to how the model can be improved. Models may also mislead, however, suggesting characteristics that are not really shared with what is being modeled. Fire was long taken as a model of energy transformation in the sun, for example, but nothing in the sun turned out to be burning. SFAA p. 124	**Grades 6-8** • Models are often used to think about processes that happen too slowly, too quickly, or on too small a scale to observe directly, or that are too vast to be changed deliberately, or that are potentially dangerous. • Different models can be used to represent the same thing. What kind of a model to use and how complex it should be depends on its purpose. The usefulness of a model may be limited if it is too simple or if it is needlessly complicated. Choosing a useful model is one of the instances in which intuition and creativity come into play in science, mathematics, and engineering. **Grades 9-12** • The usefulness of a model can be tested by comparing its predictions to actual observations in the real world. But a close match does not necessarily mean that the model is the only "true" model or the only one that would work. • Evidence consists of observations and data on which to base scientific explanations. Using evidence to understand interactions allows individuals to predict changes in natural and designed systems	Students in middle school and high school view models as physical copies of reality and not as conceptual representations. (NSES, p. 116) Research in developmental psychology implies that high school students may understand that the best model isn't found yet, or that different people prefer different models while waiting for more evidence, but NOT that there may be no "true" model at all. (Benchmarks) Research suggests effective learning environments should promote integration of science content, scientific inquiry skills, and "epistemic knowledge" (how we know). Further, an important part of epistemic understanding also includes students' epistemologies of the nature and purpose of scientific models because the degree to which models can serve as representations of scientific phenomena depends on students' epistemological commitment to a model as an explanatory framework of the scientific phenomena under inquiry. (Gobert et al, AERA, 2002 – Concord Consortium) Unless students are encouraged to attend to the misrepresentations of particular models, common misconceptions can be reinforced unwittingly (e.g., textbook diagrams of astronomical phenomena are NOT to scale…)	• What are your ideas about models? Pre- and Post- Assessment Survey • Modeling the Universe activity and Journal Reflections • How big is the universe? scaling demo • How old is the universe? Timeline inquiry • What's in the Universe? Tour • Modeling the Universe presentation on development of scientific models of the universe

Student inquiries should culminate in formulating an explanation or model. Models should be physical, conceptual, and mathematical. In the process of answering the questions, the students should engage in discussions and arguments that result in the revision of their explanations. These discussions should be based on scientific knowledge, the use of logic, and evidence from their investigation. This aspect of the standard emphasizes the critical abilities of analyzing an argument by reviewing current scientific understanding, weighing the evidence, and examining the logic so as to decide which explanations and models are best. In other words, although there may be several plausible explanations, they do not all have equal weight. Students should be able to use scientific criteria to find the preferred explanations.	NSES Unifying Concept: Models, evidence and explanation • Models are tentative schemes or structures that correspond to real objects, events, or classes of events, and that have explanatory power. Models help scientists and engineers understand how things work. Models take many forms, including physical objects, plans, mental constructs, mathematical equations, and computer simulations. Inquiry Abilities 9-12 NSES • Formulate and revise scientific explanations and models using logic and evidence • Recognize and analyze alternative explanations and models Learning Goals regarding Scale: By Grade 8: • Properties of systems that depend on volume, such as capacity and weight, change out of proportion to properties that depend on area, such as strength or surface processes. • As the complexity of any system increases, gaining an understanding of it depends increasingly on summaries, such as averages and ranges, and on descriptions of typical examples of that system. By Grade 12 • Representing large numbers in terms of powers of ten makes it easier to think about them and to compare things that are greatly different.	**Regarding Scale: (Benchmarks)** The range of numbers that people can grasp increases with age. No benefit comes from trying to foist exponential notation on children who can't grasp its meaning at all. It has been argued that people really can't comprehend a range of more than about 1,000 to 1 at any one moment. One can think of a meter being a thousand millimeters (they are there to be seen in a quick look at a meter stick) and that a kilometer is a thousand meters (it can be run off in a few minutes) - but one may not be able to think of a kilometer as a million millimeters. A million becomes meaningful, however, as a thousand thousands, once a thousand becomes comprehensible. Particularly important senses of scale to develop for science literacy are the immense size of the cosmos, the minute size of molecules, and the enormous age of the earth (and the life on it).	