Elaboration and Unpacking of the Practices

Grade 11, Measurement Target 1	Students are able to evaluate evidence and apply scientific reasoning related to Earth's geologic processes and the dynamic feedback between the biosphere and other Earth systems to support an argument about the continual co-evolution of Earth's systems and life on Earth.	
	Engaging in Argument from Evidence	**Constructing Explanations and Designing Solutions**
Practices[1]	• Evaluate evidence behind currently accepted explanations or solutions to determine the merits of arguments. **(HS-ESS1-5)** • Construct an oral and written argument or counter-arguments based on data and evidence. **(HS-ESS2-7)**	• Apply scientific reasoning to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion. **(HS-ESS1-6)**
Essential Knowledge and Skills	**HS-ESS1-5** • Students can evaluate the claims behind currently accepted explanations to determine the merits of arguments. • Students can evaluate the claims behind currently accepted solutions to determine the merits of arguments. • Students can evaluate the evidence behind currently accepted explanations to determine the merits of arguments. • Students can evaluate the evidence behind currently accepted solutions to determine the merits of arguments. • Students can evaluate the reasoning behind currently accepted explanations to determine the merits of arguments. • Students can evaluate the reasoning behind currently accepted solutions to determine the merits of arguments. **HS-ESS2-7** • Students can construct an oral argument based on data and evidence. • Students can construct a written argument based on data and evidence. • Students can construct an oral counter-argument based on data and evidence. • Students can construct a written counter-argument based on data and evidence.	**HS-ESS1-6** • Students can apply scientific reasoning to link evidence to the claims to assess the extent to which the reasoning and data support the explanation. • Students can apply scientific theory to link evidence to the claims to assess the extent to which the reasoning and data support the explanation. • Students can apply scientific modeling to link evidence to the claims to assess the extent to which the reasoning and data support the explanation. • Students can apply scientific reasoning to link evidence to the claims to assess the extent to which the reasoning and data support the conclusion. • Students can apply scientific theory to link evidence to the claims to assess the extent to which the reasoning and data support the conclusion. • Students can apply scientific modeling to link evidence to the claims to assess the extent to which the reasoning and data support the conclusion.

[1] These are the primary Practices associated with the Performance Expectations for this Measurement Target. Additional Practices Building to the PEs can be found on the website for the Next Generation Science Standards.

Evidence of a High Level of Performance	• Students can identify possible weaknesses in either data or an argument and explain why their criticism is justified, and recognize the criteria used to judge claims for new knowledge and the formal means by which scientific arguments are constructed.	• Students can undertake complex engineering design projects related to major local, national, or global issues. Students can evaluate research on the nature of the given problems, review others' proposed solutions, or weigh the strengths and weaknesses of various alternatives, and discern possible unanticipated effects.
Prerequisite Knowledge and Skills	• Ability to use linear equations and systems of linear equations to represent, analyze, and solve a variety of problems • Ability to analyze situations and solve problems • Knowledge of how to recognize patterns of association in bivariate data • Ability to write a scientific argument	
Student Challenges	• Some high school students believe scientists and engineers are more capable of making decisions about public issues related to science and technology than the general public. Students believe that scientists and engineers know all the facts and are not influenced by personal motives and interests. [1] • Students of all ages as well as adults may change variables one at a time to test a claim whose outcome may be construed as negative (e.g., honey makes a cake taste bad). But when the outcome is construed as positive (e.g., honey makes a cake taste good), they may hold constant what they believe is contributing to the positive outcome. [2] • Students may cite data in their arguments, but they may fail to cite sufficient evidence for claims. In addition, references to data in students' arguments often fail to articulate how specific data relate to specific claims. [3] Students may believe that data literally speak for themselves—that they are self-evident—rather than providing raw material for supporting or judging a claim. [4] • Some middle school students tend to invoke personal experiences as evidence to justify a particular hypothesis. Specifically, they seem to think of evidence as selected from what is already known or from personal experience or second-hand sources, not as information produced by experiment. [5] • Students do not necessarily consider only the evidence that is presented to them but make additional assertions about the context of the problem, or even introduce inferences that go beyond the boundaries of the evidence presented and that introduce bias in the outcome. [6]	
Common Core State Standards for Mathematics Connections	**MP.2** Reason abstractly and quantitatively. **(HS-ESS1-5), (HS-ESS1-6)** **HSN-Q.A.1** Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and define appropriate quantities for the purpose of descriptive modeling **(HS-ESS1-5), (HS-ESS1-6)** **HSN-Q.A.3** Choose a level of accuracy appropriate to limitations on measurement when reporting quantities **(HS-ESS1-5)**, **(HS-ESS1-6)** **HSF-IF.B.5** Relate the domain of a function to its graph and, where applicable, to the quantitative relationship it describes. **(HS-ESS1-6)** **HSS-ID.B.6** Represent data on two quantitative variables on a scatter plot and describe how those variables are related. **(HS-ESS1-6)**	
Common Core State Standards for ELA/Literacy Connections	**RST.11-12.1** Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. **(HS-ESS1-5)**, **(HS-ESS1-6)** **RST.11-12.8** Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. **(HS-ESS1-5)**, **(HS-ESS1-6)** **WHST.9-12.1** Write arguments focused on discipline-specific content. **(HS-ESS1-6**), **(HS-ESS2-7)** **WHST.9-12.2** Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. **(HS-ESS1-5)**	

[1] Fleming, R. (1987). High school graduates' beliefs about science-technology-society II. The interaction among science, technology, society. *Science Education, 71*, 163-186; Aikenhead, G.S. (1987). High school graduates' beliefs about science-technology-society III. Characteristics and limitations of scientific knowledge. *Science Education, 71*, 459-487.

[2] Zimmerman, C. (2000). The development of scientific reasoning skills. *Developmental Review, 20*, 99-149; Zimmerman, C. (2005). *The development of scientific reasoning skills: What psychologists contribute to an understanding of elementary science learning*. Report to the National Research Council, Committee on Science Learning Kindergarten through Eighth Grade. Washington, DC: National Research Council.

[3] Sandoval, W.A., Millwood, K.A. (2005). The quality of students' use of evidence in written scientific explanations. *Cognition and Instruction, 23*, 23-55.

[4] Driver, R., Leach, J., Millar, R., Scott, P. (1996). *Young people's images of science*. Buckingham: Open University Press; Sandoval, W.A., Millwood, K.A. (2005). The quality of students' use of evidence in written scientific explanations*. Cognition and Instruction, 23*, 23-55.

[5] Roseberry, A., Warren, B., Conant, F. (1992). *Appropriating scientific discourse: Findings from language minority classrooms.* (Working paper 1-92). Cambridge, MA: TERC; Ratcliffe, M. (1999). Evaluation of abilities in interpreting media reports of scientific research. *International Journal of Science Education, 21*, 1085-1099.

[6] Driver, R., Newton, P., Osborne, J. (2000). Establishing the norms of scientific argumentation in classrooms. *Science Education, 84*, 287-312.