Understanding Ocean Acidification – NGSS Alignment

This module was developed to build data literacy, engaging students in increasingly sophisticated modes of understanding and manipulation of data. It was completed prior to the release of the Next Generation Science Standards (NGSS)* and has not yet been adapted to fully incorporate the innovations described in the NGSS. However, a review has been undertaken to help teachers and educators understand if and how the activities in this module align with the new standards.

This document outlines the ways in which each level of the module provides learning experiences that engage students in the three dimensions of the NGSS Framework while building towards competency in targeted performance expectations. When reading this document, it should be noted that while Levels 1 and 2 provide students with opportunities to engage with data interpretation, Levels 3, 4, and 5 *more directly* relate to specific high school core ideas and blend the three dimensions of the NGSS. For this reason, Levels 1 and 2 are not included in this alignment document. Also of note, this document identifies the specific practice, core idea and concept directly associated with a performance expectation (shown in parentheses in the tables) but also includes additional practices and concepts that can help students *build toward* a standard.

Performance Expectations – High School

Interdependent Relationships in Ecosystems

> HS-LS2-6: Evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem.
Students build toward aspects of this standard by evaluating claims and evidence from computer simulations, data representations and video demonstrations regarding the changing conditions that are affecting ocean pH and coral reef ecosystems (Levels 3, 4, and 5).

Human Sustainability

> HS-ESS3-6: Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity
Students use computer simulations, data maps and graphs to illustrate the impact of anthropogenic increases in atmospheric CO_2 on ocean chemistry, marine populations and ecosystems (Levels 3, 4, and 5).

Chemical Reactions

> HS-PS1-6: Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium.
Students manipulate a computer simulation of the carbonate buffer system to explain that increases in atmospheric CO_2 produce increases in the amount of hydrogen ions in seawater. Teachers could slightly modify the student presentations in Level 5, allowing opportunities for students to construct and refine solutions to ocean acidification (Levels 3, 4, and 5).

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Science and Engineering Practices (SEPs)	High School SEP	How the SEP Is Addressed by the Module	Level				
			1	2	3	4	5
Analyzing and Interpreting Data	Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution. *Builds toward HS-ESS3-6 and LS2-6*	Students manipulate online simulation tools and/or analyze data to make reliable claims about patterns of change related to ocean acidification.			x	x	x
Using Mathematics and Computational Thinking	Use computational representations of phenomena to support claims and/or explanations. (HS-ESS3-6)	Students use computer simulations and conduct data investigations to examine how ocean chemistry is changing in response to anthropogenic increases in atmospheric CO_2			x	x	x
Constructing Explanations and Designing Solutions	Make a quantitative and/or qualitative claim regarding the relationship between dependent and independent variables. *Builds toward HS-LS2-6*	Students make quantitative claims regarding the relationship between dissolved CO_2, aragonite concentrations and/or variables of their own choosing.				x	x
	Refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. (HS-PS1-6)	Teachers could slightly modify the student presentations in Level 5, allowing opportunities for students to construct and refine solutions to ocean acidification.					x
Engaging in Argument from Evidence	Evaluate the claims, evidence, and reasoning behind currently accepted explanations or solutions to determine the merits of arguments. (HS-LS2-6)	Students evaluate claims and evidence from computer simulations, data representations and video demonstrations regarding changing conditions affecting ocean pH and coral reef ecosystems. Teachers may adapt Level 5 to better address this practice.			x	x	x

Disciplinary Core Ideas (DCIs)	High School DCI	How the DCI Is Addressed by the Module	Level				
			1	2	3	4	5
Ecosystem Dynamics, Functioning, and Resilience	**HS-LS2-C:** A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant over long periods of time under stable conditions. If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original status (i.e., the ecosystem is resilient), as opposed to becoming a very different ecosystem. Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability (HS-LS2-6).	Students understand that extreme increases in atmospheric CO_2 have caused oceans to become more acidic and that ocean acidification threatens coral reef ecosystems.			x	x	x

Weather and Climate	**HS-ESS2.D:** Current models predict that, although future regional climate changes will be complex and varied, average global temperatures will continue to rise. The outcomes predicted by global climate models strongly depend on the amounts of human-generated greenhouse gases added to the atmosphere each year and by the ways in which these gases are absorbed by the ocean and biosphere (HS-ESS3-6).	Students understand that IPCC models project atmospheric CO_2 to continue to rise over the next century. Students understand how this will impact ocean chemistry, marine populations and ecosystems.			x	x	x
Global Climate Change	**HS-ESS3.D:** Through computer simulations and other studies, important discoveries are still being made about how the ocean, the atmosphere, and the biosphere interact and are modified in response to human activities (HS-ESS3-6).	Students use computer simulations and conduct data investigations to examine how ocean chemistry, marine populations and ecosystems are changing in response to anthropogenic increases in atmospheric CO_2.			x	x	x
Chemical Reactions	**HS-PS1.B:** In many situations, a dynamic and condition-dependent balance between a reaction and the reverse reaction determines the numbers of all types of molecules present (HS-PS1-6).	Students understand that the reactions in the carbonate buffer system work in both directions.			x		x

Crosscutting Concepts (CCCs)	**High School CCC**	**How the CCC Is Addressed by the Module**	**Level**				
			1	**2**	**3**	**4**	**5**
Cause and Effect	Cause and effect relationships can be suggested and predicted for complex natural and human designed systems by examining what is known about smaller scale mechanisms within the system. *Builds toward HS-ESS3-6*	The causes and effects of ocean acidification are examined by investigating changes in pH, atmospheric CO_2, aragonite saturation levels and more.			x	x	x
Scale, Proportion, and Quantity	The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs. *Builds toward HS-LS2-6*	To understand the significance of ocean acidification, students manipulate variables using an online carbonate simulation program.			x		
System and System Models	When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models (HS-ESS3-6).	Students manipulate a carbonate simulation program, setting inputs and recording and analyzing outputs.			x	x	
Stability and Change	Much of science deals with constructing explanations of how things change and how they remain stable (HS-PS1-6; HS-LS2-6).	Students analyze computer simulations and time series graphs and construct explanations for how ocean chemistry and marine ecosystems are changing in response to anthropogenic increases in atmospheric CO_2			x	x	x