Okeanos Explorer Education Materials Collection, Volume 2: How Do We Explore?
Next Generation Science Standards Performance Expectations

Lesson 1: To Explore Strange New Worlds (MS/HS)

MIDDLE SCHOOL
No Performance Expectations

Science and Engineering Practices:

Developing and Using Models

- Develop a model to predict and/or describe phenomena.
- Develop a model to describe unobservable mechanisms.

Using Mathematics and Computational Thinking

- Use mathematical representations to describe and/or support scientific conclusions and design solutions.

Obtaining, Evaluating, and Communicating Information

- Communicate scientific and/or technical information (e.g. about a proposed object, tool, process, system) in writing and/or through oral presentations.

Crosscutting Concepts:

Patterns

- Macroscopic patterns are related to the nature of microscopic and atomic-level structure.
- Graphs, charts, and images can be used to identify patterns in data.

Scale, Proportion, and Quantity

- Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small.
- The observed function of natural and designed systems may change with scale.
- Phenomena that can be observed at one scale may not be observable at another scale.

Systems and System Models

- Systems may interact with other systems; they may have sub-systems and be a part of larger complex systems.
- Models are limited in that they only represent certain aspects of the system under study.

Connections to Engineering, Technology, and Applications of Science

Interdependence of Science, Engineering, and Technology

- Engineering advances have led to important discoveries in virtually every field of science, and scientific discoveries have led to the development of entire industries and engineered systems.

Influence of Science, Engineering and Technology on Society and the Natural World

- The uses of technologies and any limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. Thus technology use varies from region to region and over time.
- Technologies extend the measurement, exploration, modeling, and computational capacity of scientific investigations.

Connections to Nature of Science

Science is a Human Endeavor

- Scientists and engineers are guided by habits of mind such as intellectual honesty, tolerance of ambiguity, skepticism, and openness to new ideas.
- Advances in technology influence the progress of science and science has influenced advances in technology.

HIGH SCHOOL
No Performance Expectations

Science and Engineering Practices:
Developing and Using Models
- Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system.

Using Mathematics and Computational Thinking
- Create and/or revise a computational model or simulation of a phenomenon, designed device, process, or system.
- Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations.

Constructing Explanations and Designing Solutions
- Apply scientific reasoning, theory, and/or models to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion.

Obtaining, Evaluating, and Communicating Information
- Gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and usefulness of each source.

Crosscutting Concepts:
Patterns
- Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.
- Mathematical representations are needed to identify some patterns.

Cause and Effect: Mechanism and Prediction
- 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.

Scale, Proportion, and Quantity
- Some systems can only be studied indirectly as they are too small, too large, too fast, or too slow to observe directly.
- Patterns observable at one scale may not be observable or exist at other scales.
- Using the concept of orders of magnitude allows one to understand how a model at one scale relates to a model at another scale.

Systems and System Models
- Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales.

Connections to Engineering, Technology, and Applications of Science
Influence of Science, Engineering, and Technology on Society and the Natural World
- Modern civilization depends on major technological systems. Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks.
- Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks.
- New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology.

Connections to Nature of Science
Science is a Human Endeavor
- Technological advances have influenced the progress of science and science has influenced advances in technology.
- Science is a result of human endeavors, imagination, and creativity.

***Okeanos Explorer* Education Materials Collection, Volume 2: How Do We Explore?**
Next Generation Science Standards Performance Expectations

Lesson 2: Day in the Life of an Ocean Explorer (MS)

MS-PS4 Waves and Their Applications in Technologies for Information Transfer

Performance Expectations:
MS-PS4-1. Use mathematical representations to describe a simple model for waves that includes how the amplitude of a wave is related to the energy in a wave. [Clarification Statement: Emphasis is on describing waves with both qualitative and quantitative thinking.] [Assessment Boundary: Assessment does not include electromagnetic waves and is limited to standard repeating waves.]

Science and Engineering Practices:
Using Mathematics and Computational Thinking
- Use mathematical representations to describe and/or support scientific conclusions and design solutions.

Disciplinary Core Ideas:
PS4.A: Wave Properties
- A simple wave has a repeating pattern with a specific wavelength, frequency, and amplitude.

Crosscutting Concepts:
Patterns
- Graphs and charts can be used to identify patterns in data.

MS-PS4-2. Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials. [Clarification Statement: Emphasis is on both light and mechanical waves. Examples of models could include drawings, simulations, and written descriptions.] [Assessment Boundary: Assessment is limited to qualitative applications pertaining to light and mechanical waves.]

Science and Engineering Practices:
Developing and Using Models
- Develop and use a model to describe phenomena.

Disciplinary Core Ideas:
PS4.A: Wave Properties
- A sound wave needs a medium through which it is transmitted.

PS4.B: Electromagnetic Radiation
- When light shines on an object, it is reflected, absorbed, or transmitted through the object, depending on the object's material and the frequency (color) of the light.
- The path that light travels can be traced as straight lines, except at surfaces between different transparent materials (e.g., air and water, air and glass) where the light path bends.
- However, because light can travel through space, it cannot be a matter wave, like sound or water waves.

Crosscutting Concepts:
Structure and Function
- Structures can be designed to serve particular functions by taking into account properties of different materials, and how materials can be shaped and used.

MS-PS4-3. Integrate qualitative scientific and technical information to support the claim that digitized signals are a more reliable way to encode and transmit information than analog signals. [Clarification Statement: Emphasis is on a basic understanding that waves can be used for communication purposes. Examples could include using fiber optic cable to transmit light pulses, radio wave pulses in wifi devices, and conversion of stored binary patterns to make sound or text on a computer screen.] [Assessment Boundary: Assessment does not include binary counting. Assessment does not include the specific mechanism of any given device.]

Science and Engineering Practices:
Obtaining, Evaluating, and Communicating Information
- Integrate qualitative scientific and technical information in written text with that contained in media and visual displays to clarify claims and findings.

Disciplinary Core Ideas:
PS4.C: Information Technologies and Instrumentation
- Digitized signals (sent as wave pulses) are a more reliable way to encode and transmit information.

Crosscutting Concepts:
Structure and Function
- Structures can be designed to serve particular functions.

Connections to Engineering, Technology, and Applications of Science
Influence of Science, Engineering, and Technology on Society and the Natural World
- Technologies extend the measurement, exploration, modeling, and computational capacity of scientific investigations.

Connections to Nature of Science
Science is a Human Endeavor
- Advances in technology influence the progress of science and science has influenced advances in technology.

Common Core State Standards Connections:
ELA/Literacy –
RST.6-8.1 Cite specific textual evidence to support analysis of science and technical texts.
RST.6-8.2 Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions.
RST.6-8.9 Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic.
WHST.6-8.9 Draw evidence from informational texts to support analysis, reflection, and research.
Mathematics –
MP.2 Reason abstractly and quantitatively.
MP.4 Model with mathematics.
7.RP.A.2 Recognize and represent proportional relationships between quantities.

MS-ETS1 Engineering Design

Performance Expectations:
MS-ETS1-2. Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

Science and Engineering Practices:
Engaging in Argument from Evidence
- Evaluate competing design solutions based on jointly developed and agreed-upon design criteria.

Disciplinary Core Ideas:
ETS1.B: Developing Possible Solutions
- There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem.

Crosscutting Concepts:
None

MS-ETS1-3. Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.

Science and Engineering Practices:
Analyzing and Interpreting Data
- Analyze and interpret data to determine similarities and differences in findings.

Disciplinary Core Ideas:
ETS1.B: Developing Possible Solutions
- There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem.
- Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors.

ETS1.C: Optimizing the Design Solution
- Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process—that is, some of those characteristics may be incorporated into the new design.

Crosscutting Concepts:
None

MS-ETS1-4. Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

Science and Engineering Practices:
Developing and Using Models
- Develop a model to generate data to test ideas about designed systems, including those representing inputs and outputs.

Disciplinary Core Ideas:
ETS1.B: Developing Possible Solutions
- A solution needs to be tested, and then modified on the basis of the test results, in order to improve it.
- Models of all kinds are important for testing solutions.

ETS1.C: Optimizing the Design Solution
- The iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution.

Crosscutting Concepts:
None

Common Core Standards Connections:
ELA/Literacy –
RST.6-8.1 Cite specific textual evidence to support analysis of science and technical texts.
RST.6-8.7 Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).
RST.6-8.9 Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic.
WHST.6-8.7 Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration.
WHST.6-8.9 Draw evidence from informational texts to support analysis, reflection, and research.
Mathematics –
MP.2 Reason abstractly and quantitatively.

Additional Science and Engineering Practices:

Asking Questions and Defining Problems

- Define a design problem that can be solved through the development of an object, tool, processor system and includes multiple criteria and constraints, including scientific knowledge that may limit possible solutions.

Developing and Using Models

- Develop and/or use a model to predict and/or describe phenomena.
- Develop a model to describe unobservable mechanisms.
- Develop and/or use a model to generate data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs, and those at unobservable scales.

Planning and Carrying Out Investigations

- Conduct an investigation and evaluate the experimental design to produce data to serve as the basis for evidence that can meet the goals of the investigation.

Constructing Explanations and Designing Solutions

- Construct an explanation using models or representations.
- Apply scientific reasoning to show why the data or evidence is adequate for the explanation or conclusion.
- Undertake a design project, engaging in the design cycle, to construct and/or implement a solution that meets specific design criteria and constraints.
- Optimize performance of a design by prioritizing criteria, making tradeoffs, testing, revising, and re-testing.

Obtaining, Evaluating, and Communicating Information

- Critically read scientific texts adapted for classroom use to determine the central ideas and/or obtain scientific and/or technical information to describe patterns in and/or evidence about the natural and designed world(s).

Additional Crosscutting Concepts:

Patterns

- Patterns in rates of change and other numerical relationships can provide information about natural and human designed systems.
- Patterns can be used to identify cause and effect relationships.

Cause and Effect

- Cause and effect relationships may be used to predict phenomena in natural or designed systems.

Energy and Matter

- Energy may take different forms (e.g. energy in fields, thermal energy, energy of motion).
- The transfer of energy can be tracked as energy flows through a designed or natural system.

Influence of Science, Engineering, and Technology on Society and the Natural World

- The uses of technologies and limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions.

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Lesson 3: Wet Maps (MS)

No Performance Expectations

Science and Engineering Practices:

Developing and Using Models
- Evaluate limitations of a model for a proposed object or tool.
- Develop and use a model to describe phenomena.

Analyzing and Interpreting Data
- Construct, analyze, and/or interpret graphical displays of data and/or large data sets to identify linear and nonlinear relationships.
- Use graphical displays (e.g., maps, charts, graphs, and/or tables) of large data sets to identify temporal and spatial relationships.
- Analyze and interpret data to provide evidence for phenomena.

Crosscutting Concepts:

Patterns
- Graphs, charts and images can be used to identify patterns in data..

Systems and System Models
- Models can be used to represent systems and their interactions.
- Models are limited in that they only represent certain aspects of the system under study.

Structure and Function
- Structures can be designed to serve particular functions by taking into account properties of different materials, and how materials can be shaped and used.

Lesson 4: Mapping the Deep-ocean Floor (MS)

No Performance Expectations

Science and Engineering Practices:

Developing and Using Models

- Evaluate limitations of a model for a proposed object or tool.
- Develop and use a model to describe phenomena.

Analyzing and Interpreting Data

- Construct, analyze, and/or interpret graphical displays of data and/or large data sets to identify linear and nonlinear relationships.
- Use graphical displays (e.g., maps, charts, graphs, and/or tables) of large data sets to identify temporal and spatial relationships.
- Analyze and interpret data to provide evidence for phenomena.

Crosscutting Concepts:

Patterns

- Graphs, charts and images can be used to identify patterns in data.

Systems and System Models

- Models can be used to represent systems and their interactions.
- Models are limited in that they only represent certain aspects of the system under study.

Connections to Engineering, Technology, and Applications of Science

Influence of Science, Engineering, and Technology on Society and the Natural World

- Technologies extend the measurement, exploration, modeling, and computational capacity of scientific investigations.

Connections to Nature of Science

Science is a Human Endeavor

- Advances in technology influence the progress of science and science has influenced advances in technology.

Okeanos Explorer Education Materials Collection, Volume 2: How Do We Explore?
Next Generation Science Standards Performance Expectations

Lesson 5: Watching in 3D (HS)

HS-PS4 Waves and Their Applications in Technologies for Information Transfer

Performance Expectations:
HS-PS4-1. Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media. [Clarification Statement: Examples of data could include electromagnetic radiation traveling in a vacuum and glass, sound waves traveling through air and water, and seismic waves traveling through the Earth.] [Assessment Boundary: Assessment is limited to algebraic relationships and describing those relationships qualitatively.]

Science and Engineering Practices:
Using Mathematics and Computational Thinking
- Use mathematical representations of phenomena or design solutions to describe and/or support claims and/or explanations.

Disciplinary Core Ideas:
PS4.A: Wave Properties
- The wavelength and frequency of a wave are related to one another by the speed of travel of the wave, which depends on the type of wave and the medium through which it is passing.

Crosscutting Concepts:
Cause and Effect
- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.

HS-PS4-5. Communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy.* [Clarification Statement: Examples could include solar cells capturing light and converting it to electricity; medical imaging; and communications technology.] [Assessment Boundary: Assessments are limited to qualitative information. Assessments do not include band theory.]

Science and Engineering Practices:
Obtaining, Evaluating, and Communicating Information
- Communicate technical information or ideas (e.g. about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically).

Disciplinary Core Ideas:
PS4.A: Wave Properties
- Information can be digitized (e.g., a picture stored as the values of an array of pixels); in this form, it can be stored reliably in computer memory and sent over long distances as a series of wave pulses.

PS4.C: Information Technologies and Instrumentation
- Multiple technologies based on the understanding of waves and their interactions with matter are part of everyday experiences in the modern world (e.g., medical imaging, communications, scanners) and in scientific research. They are essential tools for producing, transmitting, and capturing signals and for storing and interpreting the information contained in them.

Crosscutting Concepts:
Cause and Effect
- Systems can be designed to cause a desired effect.

Connections to Engineering, Technology, and Applications of Science
Influence of Science, Engineering, and Technology on Society and the Natural World
- Modern civilization depends on major technological systems.

Common Core State Standards Connections:
Mathematics –
MP.2 Reason abstractly and quantitatively.
MP.4 Model with mathematics.

Additional Science and Engineering Practices:
Asking Questions and Defining Problems

- Ask questions that arise from examining models or a theory, to clarify and/or seek additional information and relationships.

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.

Using Mathematical and Computational Thinking
- Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations.
- Apply techniques of algebra and functions to represent and solve scientific and engineering problems.

Additional Crosscutting Concepts:
Patterns
- Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena.

Cause and Effect
- Systems can be designed to cause a desired effect.

Systems and System Models
- Systems can be designed to do specific tasks.
- 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.
- Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales.
- Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models.

Connections to Engineering, Technology, and Applications of Science
Influence of Engineering, Technology, and Science on Society and the Natural World
- Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks.

Lesson 6: What's a CTD (MS)

No Performance Expectations

Science and Engineering Practices:

Developing and Using Models

- Develop and/or use a model to predict and/or describe phenomena.

Analyzing and Interpreting Data

- Construct, analyze, and/or interpret graphical displays of data and/or large data sets to identify linear and nonlinear relationships.
- Analyze and interpret data to provide evidence for phenomena.
- Analyze and interpret data to determine similarities and differences in findings.

Using Mathematics and Computational Thinking

- Use mathematical representations to describe and/or support scientific conclusions and design solutions.

Constructing Explanations and Designing Solutions

- Construct an explanation that includes qualitative or quantitative relationships between variables that predict(s) and/or describe(s) phenomena.
- Construct an explanation using models or representations.

Obtaining, Evaluating, and Communicating Information

- Communicate scientific and/or technical information (e.g. about a proposed object, tool, process, system) in writing and/or through oral presentations.

Crosscutting Concepts:

Patterns

- Patterns can be used to identify cause and effect relationships.
- Graphs, charts, and images can be used to identify patterns in data.

Cause and Effect: Mechanism and Prediction

- Cause and effect relationships may be used to predict phenomena in natural or designed systems.

Systems and System Models

- Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems.
- Models are limited in that they only represent certain aspects of the system under study.

Connections to Engineering, Technology, and Applications of Science

Interdependence of Science, Engineering, and Technology

Engineering advances have led to important discoveries in virtually every field of science, and scientific discoveries have led to the development of entire industries and engineered systems.

Influence of Science, Engineering and Technology on Society and the Natural World

The uses of technologies and any limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. Thus technology use varies from region to region and over time.

Lesson 7: The Oceanographic Yo-yo (MS)

No Performance Expectations

Science and Engineering Practices:

Asking Questions and Defining Problems

- Ask questions that arise from careful observation of phenomena, models, or unexpected results, to clarify and/or seek additional information.
- Ask questions that require sufficient and appropriate empirical evidence to answer.
- Ask questions that can be investigated within the scope of the classroom, outdoor environment, and museums and other public facilities with available resources and, when appropriate, frame a hypothesis based on observations and scientific principles.

Developing and Using Models

- Evaluate limitations of a model for a proposed object or tool.
- Develop and/or use a model to predict and/or describe phenomena.
- Develop and/or use a model to generate data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs, and those at unobservable scales.

Analyzing and Interpreting Data

- Construct, analyze, and/or interpret graphical displays of data and/or large data sets to identify linear and nonlinear relationships.
- Analyze and interpret data to provide evidence for phenomena.
- Analyze and interpret data to determine similarities and differences in findings.

Using Mathematics and Computational Thinking

- Use mathematical representations to describe and/or support scientific conclusions and design solutions.

Constructing Explanations and Designing Solutions

- Construct an explanation that includes qualitative or quantitative relationships between variables that predict(s) and/or describe(s) phenomena.
- Construct an explanation using models or representations.
- Apply scientific ideas, principles, and/or evidence to construct, revise and/or use an explanation for real-world phenomena, examples, or events.
- Apply scientific reasoning to show why the data or evidence is adequate for the explanation or conclusion.

Obtaining, Evaluating, and Communicating Information

- Critically read scientific texts adapted for classroom use to determine the central ideas and/or obtain scientific and/or technical information to describe patterns in and/or evidence about the natural and designed world(s).

Connections to Nature of Science

Scientific Knowledge is Based on Empirical Evidence

- Science disciplines share common rules of obtaining and evaluating empirical evidence.

Crosscutting Concepts:

Patterns

- Patterns in rates of change and other numerical relationships can provide information about natural and human designed systems.
- Patterns can be used to identify cause and effect relationships.
- Graphs, charts, and images can be used to identify patterns in data.

Cause and Effect: Mechanism and Prediction

- Cause and effect relationships may be used to predict phenomena in natural or designed systems.

Systems and System Models

- Systems may interact with other systems; they may have sub-systems and be a part of larger complex systems.
- Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems.
- Models are limited in that they only represent certain aspects of the system under study.

Stability and Change

- Small changes in one part of a system might cause large changes in another part.

Connections to Engineering, Technology, and Applications of Science

Interdependence of Science, Engineering, and Technology

- Engineering advances have led to important discoveries in virtually every field of science, and scientific discoveries have led to the development of entire industries and engineered systems.

Influence of Science, Engineering, and Technology on Society and the Natural World

- The use of technologies and any limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. Thus technology use varies from region to region and over time.

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Lesson 8: Quest for Anomalies (HS)

No Performance Expectations

Science and Engineering Practices:

Developing and Using Models

- Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system.
- Develop and/or use a model (including mathematical and computational) to generate data to support explanations, predict phenomena, analyze systems, and/or solve problems.

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.

Using Mathematics and Computational Thinking

- Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations.

Constructing Explanations and Designing Solutions

- Apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects.

Obtaining, Evaluating, and Communicating Information

- Compare, integrate and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem.

Crosscutting Concepts:

Patterns

- Mathematical representations are needed to identify some patterns.
- Empirical evidence is needed to identify patterns.

Cause and Effect: Mechanism and Prediction

- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.
- 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.

Systems and System Models

- Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales.

Connections to Engineering, Technology, and Applications of Science

Interdependence of Science, Engineering, and Technology

Engineering advances have led to important discoveries in virtually every field of science, and scientific discoveries have led to the development of entire industries and engineered systems.

Influence of Science, Engineering, and Technology on Society and the Natural World

The use of technologies and any limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. Thus technology use varies from region to region and over time.

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Lesson 9: Invent a Robot (MS)

MS PS2 Motion and Stability: Forces and Interactions

Performance Expectations:
MS-PS2-2. Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object. [Clarification Statement: Emphasis is on balanced (Newton's First Law) and unbalanced forces in a system, qualitative comparisons of forces, mass and changes in motion (Newton's Second Law), frame of reference, and specification of units.] [Assessment Boundary: Assessment is limited to forces and changes

Science and Engineering Practices:
None

Disciplinary Core Ideas:
PS2.A: Forces and Motion
- The motion of an object is determined by the sum of the forces acting on it; if the total force on the object is not zero, its motion will change. The greater the mass of the object, the greater the force needed to achieve the same change in motion. For any given object, a larger force causes a larger change in motion.

Crosscutting Concepts:
None

Common Core State Standards Connections:
Mathematics-
7.EE.B.4 Use variables to represent quantities in a real-world or mathematical problem, and construct simple equations and inequalities to solve problems by reasoning about the quantities.

MS-ETS1 Engineering Design

Performance Expectations:
MS-ETS1-1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

Science and Engineering Practices:
Asking Questions and Defining Problems
- Define a design problem that can be solved through the development of an object, tool, process or system and includes multiple criteria and constraints, including scientific knowledge that may limit possible solutions.

Disciplinary Core Ideas:
ETS1.A: Defining and Delimiting Engineering Problems
- The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that are likely to limit possible solutions.

Crosscutting Concepts:
None

Connections to Engineering, Technology and Applications of Science
Influence of Science, Engineering, and Technology on Society and the Natural World
- All human activity draws on natural resources and has both short and long-term consequences, positive as well as negative, for the health of people and the natural environment.
- The uses of technologies and limitations on their use are driven by individual or societal needs, desires, and values;

by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions.

MS-ETS1-3. Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.

Science and Engineering Practices:
Analyzing and Interpreting Data
- Analyze and interpret data to determine similarities and differences in findings.

Disciplinary Core Ideas:
ETS1.B: Developing Possible Solutions
- There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem.
- Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors.

ETS1.C: Optimizing the Design Solution
- Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process—that is, some of those characteristics may be incorporated into the new design.

Crosscutting Concepts: none

MS-ETS1-4. Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

Science and Engineering Practices:
Developing and Using Models
- Develop a model to generate data to test ideas about designed systems, including those representing inputs and outputs.

Disciplinary Core Ideas:
ETS1.B: Developing Possible Solutions
- A solution needs to be tested, and then modified on the basis of the test results, in order to improve it.
- Models of all kinds are important for testing solutions.

ETS1.C: Optimizing the Design Solution
- The iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution.

Crosscutting Concepts:
None

Additional Science and Engineering Practices:
Asking Questions and Defining Problems
- Ask questions to clarify and/or refine a model, an explanation, or an engineering problem.
- Ask questions to define a design problem that can be solved through the development of an object, tool, process or system and includes multiple criteria and constraints, including scientific knowledge that may limit possible solutions.

Developing and Using Models
- Evaluate limitations of a model for a proposed object or tool.
- Develop or modify a model—based on evidence – to match what happens if a variable or component of a system is changed.
- Use and/or develop a model of simple systems with uncertain and less predictable factors.

Using Mathematics and Computational Thinking

- Create algorithms (a series of ordered steps) to solve a problem.

Engaging in Argument from Evidence

- Evaluate competing design solutions based on jointly developed and agreed-upon design criteria.

Constructing Explanations and Designing Solutions

- Apply scientific ideas or principles to design, construct, and/or test a design of an object, tool, process or system.
- Undertake a design project, engaging in the design cycle, to construct and/or implement a solution that meets specific design criteria and constraints.
- Optimize performance of a design by prioritizing criteria, making tradeoffs, testing, revising, and re-testing.

Additional Crosscutting Concepts:

Cause and Effect

- Cause and effect relationships may be used to predict phenomena in natural or designed systems.

Scale, Proportion and Quantity

- The observed function of natural and designed systems may change with scale.

Systems and System Models

- Systems may interact with other systems; they may have sub-systems and be a part of larger complex systems.
- Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems.
- Models are limited in that they only represent certain aspects of the system under study.

Energy and Matter: Flows, Cycles, and Conservation

- Energy may take different forms (e.g. energy in fields, thermal energy, energy of motion).
- The transfer of energy can be tracked as energy flows through a designed or natural system.

Structure and Function

- Structures can be designed to serve particular functions by taking into account properties of different materials, and how materials can be shaped and used.

Lesson 10: What *Little Herc* Saw (MS)

MS-LS2 Ecosystems: Interactions, Energy, and Dynamics

Performance Expectations:
MS-LS2-1. Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem. [Clarification Statement: Emphasis is on cause and effect relationships between resources and growth of individual organisms and the numbers of organisms in ecosystems during periods of abundant and scarce resources.]

Science and Engineering Practices:
Analyzing and Interpreting Data
- Analyze and interpret data to provide evidence for phenomena.

Disciplinary Core Ideas:
LS2.A: Interdependent Relationships in Ecosystems
- Organisms, and populations of organisms, are dependent on their environmental interactions both with other living things and with nonliving factors.

Crosscutting Concepts:
Cause and Effect
- Cause and effect relationships may be used to predict phenomena in natural or designed systems.

MS-LS2-5. Evaluate competing design solutions for maintaining biodiversity and ecosystem services.* [Clarification Statement: Examples of ecosystem services could include water purification, nutrient recycling, and prevention of soil erosion. Examples of design solution constraints could include scientific, economic, and social considerations.]

Science and Engineering Practices:
None

Disciplinary Core Ideas:
LS2.C: Ecosystem Dynamics, Functioning, and Resilience
- Biodiversity describes the variety of species found in Earth's terrestrial and oceanic ecosystems. The completeness or integrity of an ecosystem's biodiversity is often used as a measure of its health.

LS4.D: Biodiversity and Humans
- Changes in biodiversity can influence humans' resources, such as food, energy, and medicines, as well as ecosystem services that humans rely on—for example, water purification and recycling.

Crosscutting Concepts:
Stability and Change
- Small changes in one part of a system might cause large changes in another part.

Connections to Engineering, Technology, and Applications of Science
Influence of Science, Engineering, and Technology on Society and the Natural World
- The use of technologies and any limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. Thus technology use varies from region to region and over time.

Additional Science and Engineering Practices:

Asking Questions and Defining Problems

- Ask questions that arise from careful observation of phenomena, models, or unexpected results, to clarify and/or seek additional information.
- Ask questions to identify and/or clarify evidence and/or the premise(s) of an argument.
- Ask questions that require sufficient and appropriate empirical evidence to answer.

Plan and Carry out Investigations

- Conduct an investigation and/or evaluate and/or revise the experimental design to produce data to serve as the basis for evidence that meet the goals of the investigation.
- Collect data to produce data to serve as the basis for evidence to answer scientific questions or test design solutions under a range of conditions.

Analyze and Interpret Data

- Analyze and interpret data to provide evidence for phenomena.
- Consider limitations of data analysis (e.g., measurement error), and/or seek to improve precision and accuracy of data with better technological tools and methods (e.g., multiple trials).
- Analyze and interpret data to determine similarities and differences in findings.

Using Mathematical and Computational Thinking

- Use mathematical representations to describe and/or support scientific conclusions and design solutions.
- Apply mathematical concepts and/or processes (such as ratio, rate, percent, basic operations, and simple algebra) to scientific and engineering questions and problems.

Constructing Explanations and Designing Solutions

- Apply scientific ideas, principles, and/or evidence to construct, revise and/or use an explanation for real-world phenomena, examples, or events.
- Apply scientific reasoning to show why the data or evidence is adequate for the explanation or conclusion.

Obtaining, Evaluating, and Communicating Information

- Critically read scientific texts adapted for classroom use to determine the central ideas and/or obtain scientific and/or technical information to describe patterns in and/or evidence about the natural and designed world(s).

Additional Crosscutting Concepts:

Scale, Proportion and Quantity

- Proportional relationships (e.g., speed as the ratio of distance traveled to time taken) among different types of quantities provide information about the magnitude of properties and processes.

Okeanos Explorer Education Materials Collection, Volume 2: How Do We Explore?
Next Generation Science Standards Performance Expectations

Lesson 11: Through Robot Eyes (HS)

No Performance Expectations

Science and Engineering Practices:

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
- Consider limitations of data analysis (e.g., measurement error, sample selection) when analyzing and interpreting data.

Using Mathematics and Computational Thinking

- Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations
- Apply techniques of algebra and functions to represent and solve scientific and engineering problems.

Obtaining, Evaluating, and Communicating Information

- Critically read scientific literature adapted for classroom use to determine the central ideas or conclusions and/or to obtain scientific and/or technical information to summarize complex evidence, concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms
- Gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and usefulness of each source.

Crosscutting Concepts:

Cause and Effect

- Systems can be designed to cause a desired effect.

Systems and System Models

- Systems can be designed to do specific tasks.
- Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models.