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Michigan K-12 Standards

# Science

November 2015


MICHIGAN Department of Education

## CONTENTS

# Overview of the Standards

## The Role of Science Standards in Michigan

According to the dictionary, a standard is "something considered by an authority or by general consent as a basis of comparison." Today's world is replete with standards documents such as standards of care, standards of quality, and even standard operating procedures. These various sets of standards serve to outline agreed-upon expectations, rules, or actions, which guide practice and provide a platform for evaluating or comparing these practices.

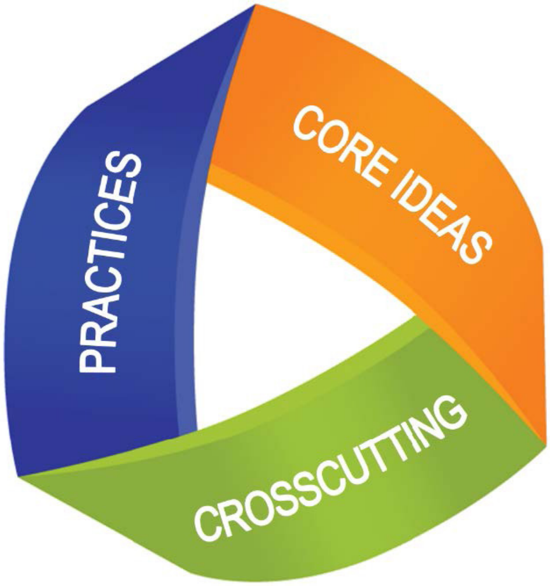
One such set of standards is the academic standards that a governing body may have for the expected outcomes of students. In Michigan, these standards, are used to outline learning expectations for Michigan's students, and are intended to guide local curriculum development and assessment of student progress. The Michigan Science Standards are performance expectations for students. They are not curriculum and they do not specify classroom instruction. Standards should be used by schools as a framework for curriculum development with the curriculum itself prescribing instructional resources, methods, progressions, and additional knowledge valued by the local community. Since Michigan is a "local control" state, local school districts and public school academies can use these standards in this manner to make decisions about curriculum, instruction, and assessment.

At the state level, these standards provide a platform for state assessments, which are used to measure how well schools are providing opportunities for all students to learn the content outlined by the standards. The standards also impact other statewide policies, such as considerations for teacher certification and credentials, school improvement, and accountability, to name a few.

The standards in this document identify the student performance outcomes for students in topics of science and engineering. These standards replace the Michigan Science Standards adopted in 2006, which were published as the Grade Level Content Expectations and High School Content Expectations for science.

## Why These Standards?

There is no question that students need to be prepared to apply basic scientific knowledge to their lives and to their careers, regardless of whether they are planning STEM based careers or not. In 2011, the National Research Council released *A Framework for K-12 Science Education*[1] which set forth guidance for science standards development based on the research on how students learn best. This extensive body of research suggests students need to be engaged in **doing science** by engaging the same practices used by scientists and engineers. Furthermore, students should engage in science and engineering practices in the context of **core ideas** that become ever more sophisticated as students move through school. Students also need to see the connections of these disciplinary-based core ideas to the **bigger science concepts that cross disciplinary lines**.




[1] "A New Conceptual Framework." *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. Washington, DC: The National Academies Press, 2012.

The proposed Michigan standards are built on this research-based framework. The framework was used in the development of the Next Generation Science Standards, for which Michigan was a lead partner. The Michigan Science Standards are derived from this effort, utilizing the student performance expectations and their relevant coding (for reference purposes). These standards are intended to guide local curricular design, leaving room for parents, teachers, and schools to surround the standards with local decisions about curriculum and instruction. Similarly, because these standards are performance expectations, they will be used to guide state assessment development.

## Organization and Structure of the Performance Expectations

Michigan's science standards are organized by grade level K-5, and then by grade span in middle school and high school. The K-5 grade level organization reflects the developmental nature of learning for elementary students in a manner that attends to the important learning progressions toward basic foundational understandings. By the time students reach traditional middle school grades (6-8), they can begin to build on this foundation to develop more sophisticated understandings of science concepts within and across disciplines. This structure also allows schools to design local courses and pathways that make sense for their students and available instructional resources.

Michigan's prior standards for science were organized by grade level through 7$^{th}$ grade. Because these standards are not a revision, but were newly designed in their entirety, it was decided that the use of the grade level designations in the traditional middle grades (6-8) would be overly inhibiting to apply universally to all schools in Michigan. Such decisions do not specifically restrict local school districts from collaborating at a local or regional level to standardize instruction at these levels. Therefore, it is recommended that each school, district, or region utilize assessment oriented grade bands (K-2, 3-5, 6-8, 9-12) to organize curriculum and instruction around the standards. MDE will provide guidance on appropriate strategies or organization for such efforts to be applied locally in each school district or public school academy.

Within each grade level/span the performance expectations are organized around topics. While each topical cluster of performance expectations addresses the topic, the wording of each performance expectation reflects the three-dimensions of science learning outlined in *A Framework for K-12 Science Education*: cross-cutting concepts, disciplinary core ideas, and science and engineering practices.

### Cross Cutting Concepts (CCC)

The seven Crosscutting Concepts outlined by the *Framework for K-12 Science Education* are the overarching and enduring understandings that provide an organizational framework under which students can connect the core ideas from the various disciplines into a "cumulative, coherent, and usable understanding of science and engineering" (*Framework*, pg. 83). These crosscutting concepts are:

1. Patterns
2. Cause and Effect
3. Scale, Proportion, and Quantity
4. Systems and System Models
5. Energy and Matter in Systems
6. Structure and Function
7. Stability and Change of Systems

### Disciplinary Core Ideas (DCI)

The crosscutting concepts cross disciplines. However within each discipline are core ideas that are developed across grade spans, increasing in sophistication and depth of understanding. Each performance expectation (PE) is coded to a DCI. These disciplinary core ideas and codes are:

1. Life Sciences (LS)
2. Physical Sciences (PS)
3. Earth and Space Sciences (ESS)
4. Engineering, Technology, and Applications of Science (ETS)

### Coding Hierarchy

Based upon the Framework and development of the Next Generation Science Standards effort, each performance expectation of the Michigan Science Standards is identified with a reference code. Each performance expectation (PE) code starts out with the grade level, followed by the disciplinary core idea (DCI) code, and ending with the sequence number of the PE within the DCI. So for example, K-PS3-2 is a kindergarten PE, linked to the 3rd physical science DCI (i.e., Energy), and is the second in sequence of kindergarten PEs linked to the PS3. These codes are used in MSS and NGSS Science Resources to identify relevant connections for standards.

### Science and Engineering Practices (SEP)

In addition to the Crosscutting Concepts and Disciplinary Core Ideas, the National Research Council has outlined 8 practices for K-12 science classrooms that describe ways students should be engaged in the classroom as a reflection of the practices of actual scientists and engineers. When students “do” science, the learning of the content becomes more meaningful. Lessons should be carefully designed so that students have opportunities to not only learn the essential science content, but to practice being a scientist or engineer. These opportunities set the stage for students to transition to college or directly into STEM careers.

Listed below are the Science and Engineering Practices from the *Framework*:

1. Asking questions and defining problems
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations and designing solutions
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

## Implementation

It is extremely important to remember that the research calls for instruction and assessments to blend the three dimensions (CCC, DCI, and SEP). It is this working together of the three dimensions that will allow all children to explain scientific phenomena, design solutions to problems, and build a foundation upon which they can continue to learn and be able to apply science knowledge and skills within and outside the K-12 education arena. While each PE incorporates these three dimensions into its wording, this alone does not drive student outcomes. Ultimately, student learning depends on how the standards are integrated in instructional practices in the classroom. There are several resources based on the National Research Council’s *A Framework for K-12 Science Education* that were developed for educators to utilize in planning curriculum, instruction, and professional development. These include resources developed by Michigan K-12 and higher education educators, with plans to develop more guided by the needs of the field as implementation moves forward. This includes assessment guidance for the Michigan Department of Education, local districts, and educators.

## Michigan Specific Contexts

Because the student performance expectations were developed to align to a general context for all learners, the Michigan Department of Education (MDE) works with a variety of stakeholders to identify Michigan-specific versions of the standards for student performance expectations that address issues directly relevant to our state such as its unique location in the Great Lakes Basin, Michigan-specific flora and fauna, and our state's rich history and expertise in scientific research and engineering. These versions of the performance expectations allow for local, regional, and state-specific contexts for learning and assessment. In addition to the specific performance expectations that frame more general concepts and phenomena in a manner that is directly relevant to our state, there are also a number of performance expectations which allow for local, regional, or state-specific problems to be investigated by students, or for students to demonstrate understandings through more localized contexts. Both of these types of performance expectations are identified in the following standards, as well as in the accompanying guidance document, which also identifies both clarification statements and assessment boundaries. The Michigan specific performance expectations should be used by educators to frame local assessment efforts. State level assessments will specifically address the performance expectations with Michigan-specific contexts.

MDE is collaborating with multiple statewide partners to generate a list of support materials for the state standards that focuses on resources and potential strategies for introducing or exploring DCIs through a local, regional, or statewide lens to make the learning more engaging and authentic. These contextual connections are not included in the specific performance expectations, as educators should merely use these as recommendations for investigation with students, and assessment developers have the opportunity to use these to develop specific examples or scenarios from which students would demonstrate their general understanding. This approach provides the opportunity for educators to draw upon Michigan's natural environment and rich history and resources in engineering design and scientific research to support student learning.

## Michigan Educator Guidance

**The Michigan Science Standards within this document are the performance expectations for students in grades K-12 for science and engineering practices, cross cutting concepts, and disciplinary core ideas of science and engineering.** In order to be able to develop and guide instruction to address the standards for all students, Michigan educators will need access to a range of guidance and resources that provide additional support for the teaching and learning of science. This guidance will be developed and shared with Michigan educators following the adoption of the proposed standards. The MDE provides additional guidance based upon educator needs and requests, and utilizes support from practicing Michigan educators and educational leaders to develop such guidance or tools to aid in the implementation of the standards.

Accompanying this standards document will be a range of resources provided to educators and assessment developers to help frame the learning context and instructional considerations of the performance expectations. Such guidance will include appropriate connections and references to the Science and Engineering Practices (SEP), the Disciplinary Core Ideas (DCI), and Cross Cutting Concepts (CCC) that frame each performance expectation. External partners, including the MiSTEM Network, Michigan Science Teachers Association, and National Science Teachers Association, and professional development providers in Michigan, will utilize the coding references of the standards to provide additional resources to Michigan educators.

## Kindergarten Performance Expectations

### Forces and Interactions: Pushes and Pulls

K-PS2-1 Plan and conduct an investigation to compare the effects of different strengths or different directions of pushes and pulls on the motion of an object.

K-PS2-2 Analyze data to determine if a design solution works as intended to change the speed or direction of an object with a push or a pull.*

### Interdependent Relationships in Ecosystems: Animals, Plants, and Their Environment

K-LS1-1 Use observations to describe patterns of what plants and animals (including humans) need to survive.**

K-ESS2-2 Construct an argument supported by evidence for how plants and animals (including humans) can change the environment to meet their needs.

K-ESS3-1 Use a model to represent the relationship between the needs of different plants or animals (including humans) and the places they live.

K-ESS3-3 Communicate solutions that will reduce the impact of humans on the land, water, air, and/or other living things in the local environment.* **

### Weather and Climate

K-PS3-1 Make observations to determine the effect of sunlight on Earth's surface.

K-PS3-2 Use tools and materials to design and build a structure that will reduce the warming effect of sunlight on an area.*

K-ESS2-1 Use and share observations of local weather conditions to describe patterns over time.**

K-ESS3-2 Ask questions to obtain information about the purpose of weather forecasting to prepare for, and respond to, severe weather.* **

### Engineering Design

K-2-ETS1-1 Ask questions, make observations, and gather information about a situation people want to change to define a simple problem that can be solved through the development of a new or improved object or tool.

K-2-ETS1-2 Develop a simple sketch, drawing, or physical model to illustrate how the shape of an object helps it function as needed to solve a given problem.

K-2-ETS1-3 Analyze data from tests of two objects designed to solve the same problem to compare the strengths and weaknesses of how each performs.

* Integrates traditional science content with engineering. Includes a Michigan specific performance expectation.
** Allow for local, regional, or Michigan specific contexts or examples in teaching and assessment.

## 1st Grade Performance Expectations

### Waves: Light and Sound

1-PS4-1 Plan and conduct investigations to provide evidence that vibrating materials can make sound and that sound can make materials vibrate.

1-PS4-2 Make observations to construct an evidence-based account that objects can be seen only when illuminated.

1-PS4-3 Plan and conduct an investigation to determine the effect of placing objects made with different materials in the path of a beam of light.

1-PS4-4 Use tools and materials to design and build a device that uses light or sound to solve the problem of communicating over a distance.*

### Structure, Function, and Information Processing

1-LS1-1 Use materials to design a solution to a human problem by mimicking how plants and/or animals use their external parts to help them survive, grow, and meet their needs.*

1-LS1-2 Read texts and use media to determine patterns in behavior of parents and offspring that help offspring survive.

1-LS3-1 Make observations to construct an evidence-based account that young plants and animals are like, but not exactly like, their parents.

### Space Systems: Patterns and Cycles

1-ESS1-1 Use observations of the sun, moon, and stars to describe patterns that can be predicted.

1-ESS1-2 Make observations at different times of year to relate the amount of daylight to the time of year.**

### Engineering Design

K-2-ETS1-1 Ask questions, make observations, and gather information about a situation people want to change to define a simple problem that can be solved through the development of a new or improved object or tool.

K-2-ETS1-2 Develop a simple sketch, drawing, or physical model to illustrate how the shape of an object helps it function as needed to solve a given problem.

K-2-ETS1-3 Analyze data from tests of two objects designed to solve the same problem to compare the strengths and weaknesses of how each performs.

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## 2nd Grade Performance Expectations

### Structure and Properties of Matter

2-PS1-1 Plan and conduct an investigation to describe and classify different kinds of materials by their observable properties.

2-PS1-2 Analyze data obtained from testing different materials to determine which materials have the properties that are best suited for an intended purpose.*

2-PS1-3 Make observations to construct an evidence-based account of how an object made of a small set of pieces can be disassembled and made into a new object.

2-PS1-4 Construct an argument with evidence that some changes caused by heating or cooling can be reversed and some cannot.

### Interdependent Relationships in Ecosystems

2-LS2-1 Plan and conduct an investigation to determine if plants need sunlight and water to grow.**

2-LS2-2 Develop a simple model that mimics the function of an animal in dispersing seeds or pollinating plants.*

2-LS4-1 Make observations of plants and animals to compare the diversity of life in different habitats.**

### Earth's Systems: Processes that Shape the Earth

2-ESS1-1 Use information from several sources to provide evidence that Earth events can occur quickly or slowly.*

2-ESS2-1 Compare multiple solutions designed to slow or prevent wind or water from changing the shape of the land.* **

2-ESS2-2 Develop a model to represent the shapes and kinds of land and bodies of water in an area.

**2-ESS2-2 MI Develop a model to represent the state of Michigan and the Great Lakes, or a more local land area and water body.**

2-ESS2-3 Obtain information to identify where water is found on Earth and that it can be solid or liquid.**

**2-ESS2-3 MI Obtain information to identify where fresh water is found on Earth, including the Great Lakes and Great Lakes Basin.**

### Engineering Design

K-2-ETS1-1 Ask questions, make observations, and gather information about a situation people want to change to define a simple problem that can be solved through the development of a new or improved object or tool.

K-2-ETS1-2 Develop a simple sketch, drawing, or physical model to illustrate how the shape of an object helps it function as needed to solve a given problem.

K-2-ETS1-3 Analyze data from tests of two objects designed to solve the same problem to compare the strengths and weaknesses of how each performs.

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# 3rd Grade Performance Expectations

## Forces and Interactions

3-PS2-1 Plan and conduct an investigation to provide evidence of the effects of balanced and unbalanced forces on the motion of an object.

3-PS2-2 Make observations and/or measurements of an object's motion to provide evidence that a pattern can be used to predict future motion.

3-PS2-3 Ask questions to determine cause and effect relationships of electric or magnetic interactions between two objects not in contact with each other.

3-PS2-4 Define a simple design problem that can be solved by applying scientific ideas about magnets.*

## Interdependent Relationships in Ecosystems

3-LS2-1 Construct an argument that some animals form groups that help members survive.

3-LS4-1 Analyze and interpret data from fossils to provide evidence of the organisms and the environments in which they lived long ago.**

3-LS4-3 Construct an argument with evidence that in a particular habitat some organisms can survive well, some survive less well, and some cannot survive at all.**

3-LS4-4 Make a claim about the merit of a solution to a problem caused when the environment changes and the types of plants and animals that live there may change.* **

## Inheritance and Variation of Traits: Life Cycles and Traits

3-LS1-1 Develop models to describe that organisms have unique and diverse life cycles but all have in common birth, growth, reproduction, and death.

3-LS3-1 Analyze and interpret data to provide evidence that plants and animals have traits inherited from parents and that variation of these traits exists in a group of similar organisms.

3-LS3-2 Use evidence to support the explanation that traits can be influenced by the environment.

3-LS4-2 Use evidence to construct an explanation for how the variations in characteristics among individuals of the same species may provide advantages in surviving, finding mates, and reproducing.

## Weather and Climate

3-ESS2-1 Represent data in tables and graphical displays to describe typical weather conditions expected during a particular season.

3-ESS2-2 Obtain and combine information to describe climates in different regions of the world.

3-ESS3-1 Make a claim about the merit of a design solution that reduces the impacts of a weather-related hazard.**

## Engineering Design

3-5-ETS1-1 Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.

3-5-ETS1-2 Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.

3-5-ETS1-3 Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

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# 4th Grade Performance Expectations

## Energy

4-PS3-1 Use evidence to construct an explanation relating the speed of an object to the energy of that object.

4-PS3-2 Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents.

4-PS3-3 Ask questions and predict outcomes about the changes in energy that occur when objects collide.

4-PS3-4 Apply scientific ideas to design, test, and refine a device that converts energy from one form to another.*

4-ESS3-1 Obtain and combine information to describe that energy and fuels are derived from natural resources and their uses affect the environment.

## Waves: Waves and Information

4-PS4-1 Develop a model of waves to describe patterns in terms of amplitude and wavelength and that waves can cause objects to move.

4-PS4-3 Generate and compare multiple solutions that use patterns to transfer information.*

## Structure, Function, and Information Processing

4-PS4-2 Develop a model to describe that light reflecting from objects and entering the eye allows objects to be seen.

4-LS1-1 Construct an argument that plants and animals have internal and external structures that function to support survival, growth, behavior, and reproduction.

4-LS1-2 Use a model to describe that animals receive different types of information through their senses, process the information in their brain, and respond to the information in different ways.

## Earth's Systems: Processes that Shape the Earth

4-ESS1-1 Identify evidence from patterns in rock formations and fossils in rock layers to support an explanation for changes in a landscape over time.**

**4-ESS1-1 MI Identify evidence from patterns in rock formations and fossils in rock layers to support possible explanations of Michigan's geological changes over time.**

4-ESS2-1 Make observations and/or measurements to provide evidence of the effects of weathering or the rate of erosion by water, ice, wind, or vegetation**

4-ESS2-2 Analyze and interpret data from maps to describe patterns of Earth's features.

4-ESS3-2 Generate and compare multiple solutions to reduce the impacts of natural Earth processes on humans.* **

**4-ESS3-2 MI Generate and compare multiple solutions to reduce the impacts of natural Earth processes on Michigan's people and places.**

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** Allow for local, regional, or Michigan specific contexts or examples in teaching and assessment.

## Engineering Design

3-5-ETS1-1 Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.

3-5-ETS1-2 Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.

3-5-ETS1-3 Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

# 5th Grade Performance Expectations

## Structure and Properties of Matter

5-PS1-1 Develop a model to describe that matter is made of particles too small to be seen.

5-PS1-2 Measure and graph quantities to provide evidence that regardless of the type of change that occurs when heating, cooling, or mixing substances, the total weight of matter is conserved.

5-PS1-3 Make observations and measurements to identify materials based on their properties.

5-PS1-4 Conduct an investigation to determine whether the mixing of two or more substances results in new substances.

## Matter and Energy in Organisms and Ecosystems

5-PS3-1 Use models to describe that energy in animals' food (used for body repair, growth, motion, and to maintain body warmth) was once energy from the sun.

5-LS1-1 Support an argument that plants get the materials they need for growth chiefly from air and water.

5-LS2-1 Develop a model to describe the movement of matter among plants, animals, decomposers, and the environment.

## Earth's Systems

5-ESS2-1 Develop a model using an example to describe ways the geosphere, biosphere, hydrosphere, and/or atmosphere interact.

**5-ESS2-1MI Develop a model using an example to describe ways the geosphere, biosphere, hydrosphere, and/or atmosphere interact in Michigan and the Great Lakes basin.**

5-ESS2-2 Describe and graph the amounts and percentages of water and fresh water in various reservoirs to provide evidence about the distribution of water on Earth.

**5-ESS2-2MI Describe and graph the amounts and percentages of water and fresh water in the Great Lakes to provide evidence about the distribution of water on Earth.**

5-ESS3-1 Obtain and combine information about ways individual communities use science ideas to protect the Earth's resources and environment.**

## Space Systems: Stars and the Solar System

5-PS2-1 Support an argument that the gravitational force exerted by Earth on objects is directed down.

5-ESS1-1 Support an argument that differences in the apparent brightness of the sun compared to other stars is due to their relative distances from Earth.

5-ESS1-2 Represent data in graphical displays to reveal patterns of daily changes in length and direction of shadows, day and night, and the seasonal appearance of some stars in the night sky.

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** Allow for local, regional, or Michigan specific contexts or examples in teaching and assessment.

## Engineering Design

3-5-ETS1-1 Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.

3-5-ETS1-2 Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.

3-5-ETS1-3 Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

## Middle School (Grades 6–8) Performance Expectations

### Physical Sciences (PS)

#### Structure and Properties of Matter

MS-PS1-1 Develop models to describe the atomic composition of simple molecules and extended structures.

MS-PS1-3 Gather and make sense of information to describe that synthetic materials come from natural resources and impact society.

MS-PS1-4 Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed.

#### Chemical Reactions

MS-PS1-2 Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.

MS-PS1-5 Develop and use a model to describe how the total number of atoms does not change in a chemical reaction and thus mass is conserved.

MS-PS1-6 Undertake a design project to construct, test, and modify a device that either releases or absorbs thermal energy by chemical processes.*

#### Forces and Interactions

MS-PS2-1 Apply Newton's Third Law to design a solution to a problem involving the motion of two colliding objects.*

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.

MS-PS2-3 Ask questions about data to determine the factors that affect the strength of electric and magnetic forces.

MS-PS2-4 Construct and present arguments using evidence to support the claim that gravitational interactions are attractive and depend on the masses of interacting objects.

MS-PS2-5 Conduct an investigation and evaluate the experimental design to provide evidence that fields exist between objects exerting forces on each other even though the objects are not in contact.

#### Energy

MS-PS3-1 Construct and interpret graphical displays of data to describe the relationships of kinetic energy to the mass of an object and to the speed of an object.

MS-PS3-2 Develop a model to describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system.

MS-PS3-3 Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer.*

MS-PS3-4 Plan an investigation to determine the relationships among the energy transferred, the type of matter, the mass, and the change in the average kinetic energy of the particles as measured by the temperature of the sample.

MS-PS3-5 Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object.

### Waves and Electromagnetic Radiation

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.

MS-PS4-2 Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials.

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.

## Life Sciences (LS)

### Structure, Function, and Information Processing

MS-LS1-1 Conduct an investigation to provide evidence that living things are made of cells; either one cell or many different numbers and types of cells.

MS-LS1-2 Develop and use a model to describe the function of a cell as a whole and ways parts of cells contribute to the function.

MS-LS1-3 Use argument supported by evidence for how the body is a system of interacting subsystems composed of groups of cells.

MS-LS1-8 Gather and synthesize information that sensory receptors respond to stimuli by sending messages to the brain for immediate behavior or storage as memories.

### Matter and Energy in Organisms and Ecosystems

MS-LS1-6 Construct a scientific explanation based on evidence for the role of photosynthesis in the cycling of matter and flow of energy into and out of organisms.

MS-LS1-7 Develop a model to describe how food is rearranged through chemical reactions forming new molecules that support growth and/or release energy as this matter moves through an organism.

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.**

MS-LS2-3 Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem.**

MS-LS2-4 Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.

## Interdependent Relationships in Ecosystems

MS-LS2-2 Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems.**

MS-LS2-5 Evaluate competing design solutions for maintaining biodiversity and ecosystem services.* **

## Growth, Development, and Reproduction of Organisms

MS-LS1-4 Use argument based on empirical evidence and scientific reasoning to support an explanation for how characteristic animal behaviors and specialized plant structures affect the probability of successful reproduction of animals and plants respectively.

MS-LS1-5 Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms.**

MS-LS3-1 Develop and use a model to describe why structural changes to genes (mutations) located on chromosomes may affect proteins and may result in harmful, beneficial, or neutral effects to the structure and function of the organism.

MS-LS3-2 Develop and use a model to describe why asexual reproduction results in offspring with identical genetic information and sexual reproduction results in offspring with genetic variation.

MS-LS4-5 Gather and synthesize information about the technologies that have changed the way humans influence the inheritance of desired traits in organisms.

## Natural Selection and Adaptations

MS-LS4-1 Analyze and interpret data for patterns in the fossil record that document the existence, diversity, extinction, and change of life forms throughout the history of life on Earth under the assumption that natural laws operate today as in the past.**

MS-LS4-2 Apply scientific ideas to construct an explanation for the anatomical similarities and differences among modern organisms and between modern and fossil organisms to infer evolutionary relationships.

MS-LS4-3 Analyze displays of pictorial data to compare patterns of similarities in the embryological development across multiple species to identify relationships not evident in the fully formed anatomy.

MS-LS4-4 Construct an explanation based on evidence that describes how genetic variations of traits in a population increase some individuals' probability of surviving and reproducing in a specific environment.

MS-LS4-6 Use mathematical representations to support explanations of how natural selection may lead to increases and decreases of specific traits in populations over time.

* Integrates traditional science content with engineering. Includes a Michigan specific performance expectation.
** Allow for local, regional, or Michigan specific contexts or examples in teaching and assessment.

## Earth and Space Sciences (ESS)

### Space Systems

MS-ESS1-1 Develop and use a model of the Earth-sun-moon system to describe the cyclic patterns of lunar phases, eclipses of the sun and moon, and seasons.

MS-ESS1-2 Develop and use a model to describe the role of gravity in the motions within galaxies and the solar system.

MS-ESS1-3 Analyze and interpret data to determine scale properties of objects in the solar system.

### History of Earth

MS-ESS1-4 Construct a scientific explanation based on evidence from rock strata for how the geologic time scale is used to organize Earth's 4.6-billion-year-old history.

MS-ESS2-2 Construct an explanation based on evidence for how geoscience processes have changed Earth's surface at varying time and spatial scales.

MS-ESS2-3 Analyze and interpret data on the distribution of fossils and rocks, continental shapes, and seafloor structures to provide evidence of the past plate motions.

### Earth's Systems

MS-ESS2-1 Develop a model to describe the cycling of Earth's materials and the flow of energy that drives this process.**

MS-ESS2-4 Develop a model to describe the cycling of water through Earth's systems driven by energy from the sun and the force of gravity.**

MS-ESS3-1 Construct a scientific explanation based on evidence for how the uneven distributions of Earth's mineral, energy, and groundwater resources are the result of past and current geoscience processes.**

### Weather and Climate

MS-ESS2-5 Collect data to provide evidence for how the motions and complex interactions of air masses results in changes in weather conditions.

**MS-ESS2-5 MI Collect data to provide evidence for how the motions and complex interactions of air masses results in changes in weather conditions in Michigan due to the Great Lakes and regional geography.**

MS-ESS2-6 Develop and use a model to describe how unequal heating and rotation of the Earth cause patterns of atmospheric and oceanic circulation that determine regional climates.

MS-ESS3-5 Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century.

## Human Impacts

MS-ESS3-2 Analyze and interpret data on natural hazards to forecast future catastrophic events and inform the development of technologies to mitigate their effects.

MS-ESS3-3 Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.* **

MS-ESS3-4 Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems.

# Engineering, Technology, and Applications of Science (ETS)

## Engineering Design

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.

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

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.

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.

* Integrates traditional science content with engineering. Includes a Michigan specific performance expectation.
** Allow for local, regional, or Michigan specific contexts or examples in teaching and assessment.

## High School (Grades 9-12) Performance Expectations

### Physical Sciences (PS)

#### Structure and Properties of Matter

HS-PS1-1 Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms.

HS-PS1-3 Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.

HS-PS1-8 Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay.

HS-PS2-6 Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.*

#### Chemical Reactions

HS-PS1-2 Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties.

HS-PS1-4 Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy.

HS-PS1-5 Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs.

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.*

HS-PS1-7 Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.

#### Forces and Interactions

HS-PS2-1 Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.

HS-PS2-2 Use mathematical representations to support the claim that the total momentum of a system of objects is conserved when there is no net force on the system.

HS-PS2-3 Apply scientific and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision.*

HS-PS2-4 Use mathematical representations of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects.

HS-PS2-5 Plan and conduct an investigation to provide evidence that an electric current can produce a magnetic field and that a changing magnetic field can produce an electric current.

### Energy

HS-PS3-1 Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.

HS-PS3-2 Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative position of particles (objects).

HS-PS3-3 Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.*

HS-PS3-4 Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics).

HS-PS3-5 Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction.

### Waves and Electromagnetic Radiation

HS-PS4-1 Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.

HS-PS4-2 Evaluate questions about the advantages of using a digital transmission and storage of information.

HS-PS4-3 Evaluate the claims, evidence, and reasoning behind the idea that electromagnetic radiation can be described either by a wave model or a particle model, and that for some situations one model is more useful than the other.

HS-PS4-4 Evaluate the validity and reliability of claims in published materials of the effects that different frequencies of electromagnetic radiation have when absorbed by matter.

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.*

## Life Sciences (LS)

### Structure and Function

HS-LS1-1 Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins which carry out the essential functions of life through systems of specialized cells.

HS-LS1-2 Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.

HS-LS1-3 Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis.

## Matter and Energy in Organisms and Ecosystems

HS-LS1-5 Use a model to illustrate how photosynthesis transforms light energy into stored chemical energy.

HS-LS1-6 Construct and revise an explanation based on evidence for how carbon, hydrogen, and oxygen from sugar molecules may combine with other elements to form amino acids and/or other large carbon-based molecules.

HS-LS1-7 Use a model to illustrate that cellular respiration is a chemical process whereby the bonds of food molecules and oxygen molecules are broken and the bonds in new compounds are formed resulting in a net transfer of energy.

HS-LS2-3 Construct and revise an explanation based on evidence for the cycling of matter and flow of energy in aerobic and anaerobic conditions.

HS-LS2-4 Use mathematical representations to support claims for the cycling of matter and flow of energy among organisms in an ecosystem.**

HS-LS2-5 Develop a model to illustrate the role of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere.**

## Interdependent Relationships in Ecosystems

HS-LS2-1 Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales.

HS-LS2-2 Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales.

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.**

HS-LS2-7 Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.* **

HS-LS2-8 Evaluate the evidence for the role of group behavior on individual and species' chances to survive and reproduce.

HS-LS4-6 Create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity.**

## Inheritance and Variation of Traits

HS-LS1-4 Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms.

HS-LS3-1 Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring.

HS-LS3-2 Make and defend a claim based on evidence that inheritable genetic variations may result from: (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors.

HS-LS3-3 Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population.

## Natural Selection and Evolution

HS-LS4-1 Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence.

HS-LS4-2 Construct an explanation based on evidence that the process of evolution primarily results from four factors: (1) the potential for a species to increase in number, (2) the heritable genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for limited resources, and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment.

HS-LS4-3 Apply concepts of statistics and probability to support explanations that organisms with an advantageous heritable trait tend to increase in proportion to organisms lacking this trait.

HS-LS4-4 Construct an explanation based on evidence for how natural selection leads to adaptation of populations.

HS-LS4-5 Evaluate the evidence supporting claims that changes in environmental conditions may result in: (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species.

# Earth and Space Sciences (ESS)

## Space Systems

HS-ESS1-1 Develop a model based on evidence to illustrate the life span of the sun and the role of nuclear fusion in the sun's core to release energy that eventually reaches Earth in the form of radiation.

HS-ESS1-2 Construct an explanation of the Big Bang theory based on astronomical evidence of light spectra, motion of distant galaxies, and composition of matter in the universe.

HS-ESS1-3 Communicate scientific ideas about the way stars, over their life cycle, produce elements.

HS-ESS1-4 Use mathematical or computational representations to predict the motion of orbiting objects in the solar system.

## History of Earth

HS-ESS1-5 Evaluate evidence of the past and current movements of continental and oceanic crust and the theory of plate tectonics to explain the ages of crustal rocks.

HS-ESS1-6 Apply scientific reasoning and evidence from ancient Earth materials, meteorites, and other planetary surfaces to construct an account of Earth's formation and early history.

HS-ESS2-1 Develop a model to illustrate how Earth's internal and surface processes operate at different spatial and temporal scales to form continental and ocean-floor features.

## Earth's Systems

HS-ESS2-2 Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth systems.

HS-ESS2-3 Develop a model based on evidence of Earth's interior to describe the cycling of matter by thermal convection.

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HS-ESS2-5 Plan and conduct an investigation of the properties of water and its effects on Earth materials and surface processes.**

HS-ESS2-6 Develop a quantitative model to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere.

HS-ESS2-7 Construct an argument based on evidence about the simultaneous coevolution of Earth's systems and life on Earth.

### Weather and Climate

HS-ESS2-4 Use a model to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate.

HS-ESS3-5 Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth systems.**

### Human Sustainability

HS-ESS3-1 Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity.

HS-ESS3-2 Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.* **

HS-ESS3-3 Create a computational simulation to illustrate the relationships among management of natural resources, the sustainability of human populations, and biodiversity.**

HS-ESS3-4 Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.*

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.

**Engineering, Technology, and Applications of Science (ETS)**

### Engineering Design

HS-ETS1-1 Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.

HS-ETS1-2 Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

HS-ETS1-3 Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.

HS-ETS1-4 Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.

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