LINCOLN CONSOLIDATED SCHOOLS

LINCOLN CURRICULUM STANDARDS FOR

Science

Grade 9-12

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.

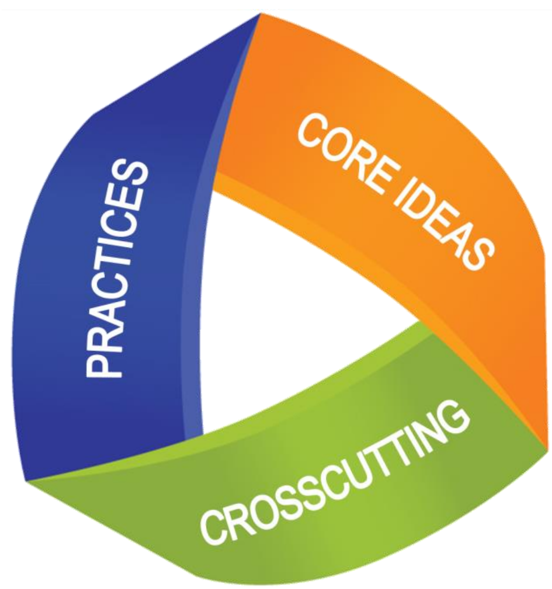
One such set of standards is the academic standards that a governing body may have for the expected outcomes of students. In Michigan, these standards, are used to outline learning expectations for Michigan's students, and are intended to guide local curriculum development and assessment of student progress. 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.



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.

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**. 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 7th 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. A list of DCIs and their codes can be found on the MDE website and in the MDE Guidance Documents.

Science and Engineering Practices
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.

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.

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 Practices). 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, the Disciplinary Core Ideas (DCI), and Cross Cutting Concepts (CCC) that frame each performance expectation. External partners, including the Michigan Mathematics and Science Center 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.

The MDE will provide ongoing support to educators through guidance and professional learning resources, which will be updated regularly. Additional information and references can be found at http://michigan.gov/science.

Science – Grades 9-12

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.

* - Integrates traditional science content with engineering. - Includes a Michigan specific performance expectation.

Science – Grades 9-12

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.

Science – Grades 9-12

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. *

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.

* - Integrates traditional science content with engineering. - Includes a Michigan specific performance expectation.

Science – Grades 9-12

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. **

* - 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.

Science – Grades 9-12

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 Adaptations

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.

Science – Grades 9-12

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.
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.

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

Science – Grades 9-12

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 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.

* - 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.