

INTRODUCTION

The *Michigan Curriculum Framework* is a resource for helping Michigan's public and private schools design, implement, and assess their core content area curricula. The content standards identified in this document are presented as models for the development of local district curriculum by the Michigan State Board of Education and the Michigan Department of Education. They represent rigorous expectations for student performance, and describe the knowledge and abilities needed to be successful in today's society. When content, instruction, and local and state assessments are aligned, they become powerful forces that contribute to the success of student achievement.

The framework presents a content and a process for developing curriculum that enables schools to realize Michigan's vision for K-12 education:

Michigan's K-12 education will ensure that all students will develop their potential in order to lead productive and satisfying lives. All students will engage in challenging and purposeful learning that blends their experiences with content knowledge and real-world applications in preparation for their adult roles, which include becoming:

- ♦ *literate individuals*
- ♦ *healthy and fit people*
- ♦ *responsible family members*
- ♦ *productive workers*
- ♦ *involved citizens*
- ♦ *self-directed, lifelong learners*

The intent of this document is to provide useful resources to districts as they strive to implement a program which ensures that all students reap the benefits of a quality education and achieve the adult roles described in Michigan's vision for K-12 education. The content standards and benchmarks serve as worthy goals for all students as they develop the knowledge and abilities inherent in their adult roles. They represent an essential component in the process of continuous school improvement, which like professional development, should be focused on improving student achievement.

We believe that efforts to set clear, common, state and/or community-based academic standards for students in a given school district or state are necessary to improve student performance. Academic standards clearly define what students should know and be able to do at certain points in their schooling to be considered proficient in specific academic areas. We believe that states and communities can benefit from working together to tap into the nation's best thinking on standards and assessments.

1996 National Education Summit Policy Statement

"Setting high standards for our children. It's the sine qua non for any other reforms anyone might want to implement. We can't judge the efficacy of ideas because we have no yardsticks by which to measure success or failure."

Louis V. Gerstner
Chairman and CEO, IBM

The framework emphasizes the importance of:

- ♦ using continuous school improvement to align all district initiatives for the purpose of increasing student achievement;
- ♦ building a curriculum based on rigorous content standards and benchmarks;
- ♦ using student achievement data to make decisions about continuous school improvement, curriculum, instruction, and professional development; and,
- ♦ incorporating research-supported teaching and learning standards into daily instructional practice.

BACKGROUND

In 1993, the Michigan Department of Education, in collaboration with representatives from five state universities, was awarded federal funding from the U.S. Department of Education to develop curriculum framework components for English language arts, mathematics, science, and geography. In addition, the Michigan Council for the Social Studies offered, and was supported by the State Board of Education, to develop a curriculum framework component for social studies which would include history, economics, and American government, and would be complementary to the geography framework.

The *Michigan Curriculum Framework* brings together the work of individual content area projects to present a unified view of curriculum, one which addresses the educational needs of the whole learner. The goal of the curriculum framework is to improve student achievement by aligning classroom instruction with core curriculum content standards and national content standards. It is designed to be used as a process for the decision-making that guides continuous school improvement. It describes curriculum, instruction, and assessment and focuses on improving program quality by aligning all the processes that affect a student's achievement of rigorous content standards.

Framework project co-directors, university representatives, and the Michigan Department of Education content area consultants met regularly with members of their content area professional organizations to design the components of the curriculum framework. Committees of teachers and university personnel worked together to draft the content standards, benchmarks, and performance standards for their specific content areas.

Co-directors met on a monthly basis to coordinate the efforts of the various content area committees in developing K-12 standards and benchmarks for their subject areas. Their purpose was to ensure that the framework represents a consistent view of curriculum across content areas. They wanted to facilitate continuous school improvement by emphasizing commonalities among the content areas with regard to professional development, assessment, and instruction.

The co-directors were guided by a Joint Steering Committee comprised of representatives from the content areas, parents, business leaders, labor leaders, house and senate staff, and educators. Joint Steering Committee members reviewed the framework projects at each phase of their development and made recommendations for improving their quality. Their insight helped the co-directors incorporate the views of all of Michigan's interested parties into the final framework document.

WHAT IS IN THE FRAMEWORK?

The framework includes the resources needed to develop a standards-based curriculum. Standards and benchmarks for English language arts, mathematics, science, and social studies are included in this edition of the framework. Standards and benchmarks for arts education, career and employability skills, health education, life management education, physical education, technology education, and world languages will be added to the next edition of the framework. The process described in the framework will be expanded to incorporate the additional core content areas when they are completed. The chart on page vi provides a list of the materials that eventually will be included in the framework document.

Tier I

Content Standards and Benchmarks

Tier I begins with a complete list of core curriculum content standards and benchmarks for grades K-12 in the areas of English language arts, mathematics, science and social science. The standards describe what all students should know and be able to do in each of the subject areas. The benchmarks indicate what students should know and be able to do at various developmental levels (i.e., early elementary school, later elementary school, middle school, and high school).

Planning

The framework includes a planning section. It provides a model for using the standards and benchmarks to create a local district curriculum as part of continuous school improvement. It discusses the importance of involving representatives from all stakeholders in the curriculum development process. In addition, it emphasizes the need for alignment among all of the processes that comprise continuous school improvement and focuses attention on placing student achievement at the center of all decision-making. It emphasizes the need for continuity in a K-12 curriculum. Continuity is developed by clearly defining benchmarks that establish increasingly complex demonstrations of rigorous standards.

Teaching and Learning

The section on teaching and learning describes standards that are the foundation to successful learning in all content areas. The standards include deep knowledge, higher-order thinking, substantive conversation, and connections to the world beyond the classroom. It illustrates the standards through sample

teaching vignettes in each of the content areas. It discusses the importance of incorporating strategies for technology, connecting with the learner, interdisciplinary learning, and making school-to-work connections into the curriculum.

Assessment System

The framework contains a section on assessment which describes the need for developing a local assessment system to monitor student growth and program effectiveness. This section of the framework is divided into three parts. The first part provides a rationale for why an assessment system is needed. The second part describes how teachers can develop performance assessments based on the content standards and benchmarks. The third part discusses important issues related to building an assessment system that aligns local assessment practices with state assessment.

Professional Development

The section on professional development lists standards for the context, content, and process of professional development experiences. It includes a process for designing professional development which aligns with school improvement, curriculum content, student learning, and assessment needs. A vignette of one teacher's personal, professional development experiences is provided to illustrate Michigan's Standards for Professional Development.

Executive Summaries and Glossary

The appendices of the framework contain executive summaries of important resources that will aid a district as it develops, implements, and monitors its local curriculum. A glossary of framework terms is also provided.

Tier II

Toolkits

Tier II contains a collection of toolkits designed to help districts with specific tasks such as conducting discrepancy analyses. There are additional toolkits to guide districts in incorporating principles associated with connecting with the learner, technology, curriculum integration, and making school-to-work connections. There are toolkits on planning subject area instructional units, designing classroom assessments, and planning a district assessment system. *(Some of the above mentioned toolkits are still under development.)*

Tier III

Resources

Tier III contains content-area specific resources that help clarify the curriculum development process described in the framework. These include resources such as the *Science Education Guidebook*, the *Mathematics Teaching and Learning Sample Activities*, *Guidelines for the Professional Development of Teachers of English Language Arts*, and *Powerful & Authentic Social Studies Standards for Teaching*. It also

contains a guidebook written specifically for parents and the business community explaining the elements of the framework.

HOW TO USE THE FRAMEWORK

District school improvement committees and curriculum development committees will find the framework and its toolkits very useful as they begin the process of creating a standards-based curriculum. Reading and discussing the contents of the framework will help school improvement committee members gain a clearer understanding of the curriculum development process. The toolkits will help subcommittees develop techniques for creating and aligning curriculum, assessment, and instruction. They will also help districts make decisions about the professional development strategies which will most effectively help their students reach targeted achievement goals.

The first step in using the framework is to make sure that all interested parties are familiar with its content. Then an analysis to determine what needs to be done should be completed. Once the district identifies the tasks that need to be completed, a plan for structuring committees and a time-line for completing the tasks should be designed.

The framework is intended for use by all districts. While the writers used the structure of a middle-sized district as a frame of reference, the content and processes it describes are equally important for large and small districts. Although private schools are not bound by the core curriculum requirements of the Michigan School Code, they may find the framework useful as a tool for curriculum development. Large districts, small districts, private schools, and public school academies may choose to modify the process to reflect their organizational structures. The number and size of committees needed to implement the framework will vary from district to district, but the task will remain the same: to align curriculum, instruction, assessment, and professional development for the purpose of increasing student achievement of rigorous content standards.

Michigan Curriculum Framework

TIER I

This document introduces the framework standards and describes the components and processes needed to develop K-12 curricula.

Introduction

Standards & Benchmarks

Planning

Teaching and Learning

Assessment System

Professional Development

Executive Summaries of Toolkits and Other Resources

Parent and Business Leader Guides (under development)

TIER II

These documents are toolkits designed to help districts achieve alignment while developing curriculum, instruction, and assessment consistent with their standards and benchmarks. (For availability, see <http://www.mde.state.mi.us>)

Discrepancy Analysis

1. Analysis of Curriculum
2. Analysis of Instruction
3. Analysis of Assessment
4. Analysis of Professional Development
5. Analysis of School Operations

Connecting with the Learner
Technology
Curriculum Integration
Connecting School-To-Work

Local Assessment System

TIER III

These resources are specific to each content area and help clarify and strengthen the curriculum development processes described in the first two tiers. (For availability, see <http://www.mde.state.mi.us>)

- Michigan Geography Framework Poster
- Analysis of Mathematics Instructional and Assessment Materials
- Mathematics Research Component
- Social Studies Curriculum Planning Guide

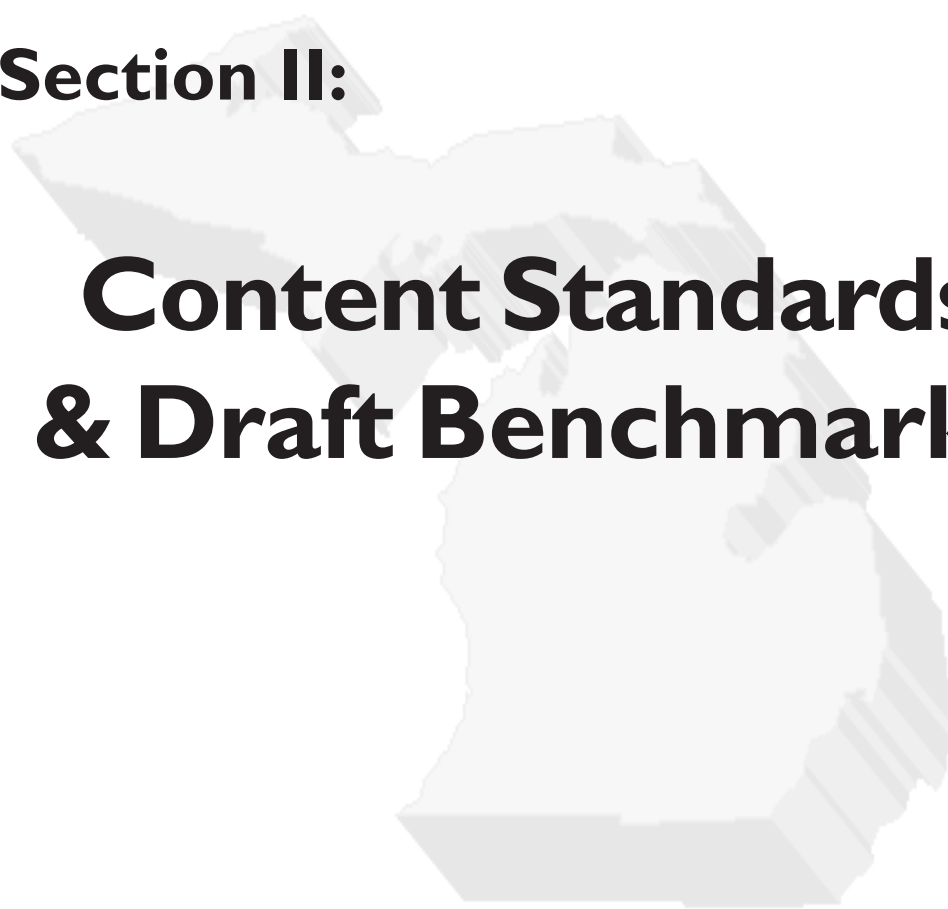
- Science Education Guidebook
- *New Directions* Science Teaching Units
- Profiles of Early Literacy Instruction in Primary Classrooms
- A Collection of English Language Arts Vignettes
- Readings from the Demonstration Projects
- Mathematics Teaching and Learning Sample Activities
- Standards Based Geography Units
- Powerful & Authentic Social Studies: Standards for Teaching and Learning

- Mathematics Assessment Framework
- The Model Assessment Items Resource Book (*Science*)
- Michigan Assessment Prototypes for Geography
- Plan for Statewide Assessment of Social Studies
- Social Studies Assessment Guide

- Guidelines for the Professional Development of Teachers of English Language Arts
- Mathematics Professional Development Component
- Powerful and Authentic Social Studies Professional Development Package
- Powerful and Authentic Social Studies Standards for Teaching

Section II:

Content Standards & Draft Benchmarks



CONTENT

STANDARDS & DRAFT BENCHMARKS

At its July 19, 1995, meeting, the Michigan State Board of Education unanimously adopted the model content standards for curriculum. The content standards provide descriptions of what students should know and be able to do in the subject areas of English language arts, social studies, mathematics and science. In addition, benchmarks in each of the content areas were drafted to further clarify the content standards. The standards and benchmarks are not a state curriculum, but are specifically designed to be used by local districts as they develop their curricula.

The model content standards for curriculum and accompanying draft benchmarks will assist in the development of quality comprehensive local curricula, foster local diversity in establishing high quality learning expectations, and give parents, as customers within an education marketplace, an accountability tool. In addition, they will serve as a basis for revisions and new test development for the MEAP and High School Proficiency Tests. They will provide a common denominator to determine how well students are performing and will assure that all students are measured on the same knowledge and skills using the same method of assessment.

Model Content Standards for Curriculum

The model content standards for curriculum were revised, based upon public input, by writing teams in each of the content areas. The Curriculum Framework Joint Steering Committee which includes representatives from business, education, government, professional organizations, and labor was extensively consulted in the development and revision of the standards. The State Board also made revisions to the standards during its July 19, 1995, meeting.

Benchmarks

The draft benchmarks provide indicators of student expectations at various developmental levels including elementary, middle school, and high school. The working draft benchmarks are the most current versions and represent the efforts made by teams of subject area specialists with input from over 2,000 Michigan citizens.

Field reviews on the benchmarks were held to gather comments from teachers, parents, administrators, and community members. Additionally, the benchmarks have been reviewed for consistency with the model content standards for curriculum. The department continues the process of field testing the benchmarks at the Curriculum Framework projects' school demonstration sites.

SOC.II.1.LE.1

SOC. Social Studies
(*Subject Area*)

II. Geographic Perspective
(*Content Strand*)

1. All students will describe, compare, and explain the locations and characteristics of places, cultures, and settlements. (People, Places and Cultures) (*Content Standard*)

LE. Later Elementary

1. Locate and describe cultures and compare the similarities and differences among the roles of women, men and families. (*Later Elementary Benchmark*)

Because the benchmarks are continuously being revised to further clarify the standards and reflect the learning needs of Michigan's students, districts should consult electronic versions in order to ensure that they are working with the most current revisions. The model content standards for curriculum and the working draft benchmarks are available through the Internet on the Department of Education's gopher server (gopher://gopher.mde.state.mi.us), and through the World Wide Web (<http://cdp.mde.state.mi.us>).

Please note: The standards and benchmarks have been coded so that districts can more easily refer to them in their curriculum, instruction, assessment, and professional development activities. The numbering system will be useful as districts conduct discrepancy analyses as part of the continuous school improvement decision-making process. One system for numbering has been applied to all of the content standards and benchmarks in an attempt to provide consistency and facilitate curriculum alignment.

The numbering system begins with the subject area. English language arts is assigned the code of ELA; Mathematics, MAT; Social Studies, SOC; and Science, SCI. The first numeral in the code is a Roman numeral; it identifies the content area strand. The second numeral is an Arabic numeral; it identifies a content standard. The letters that follow the content standard signify cluster levels such as: E (elementary), EE (early elementary), LE (later elementary), MS (middle school), and HS (high school). The third numeral is another Arabic numeral; it identifies a benchmark.

The coding system has been used to identify standards and benchmarks in the sections on assessment and teaching and learning. Please note that although one coding system is used, each set of content areas and benchmarks has some unique characteristics. For instance, the English language arts standards and benchmarks do not identify strands. It is very important to study the standards and benchmarks carefully so they can be used to their full advantage.

Science

Science is a way of making sense of the natural world. Scientists seek to describe its complexity, to explain its systems and events, and to find the patterns that allow for predictions. Science is the basis for the design of technologies that solve real-world problems.

Not all students will become scientists or engineers. But science and technology occupy ever-expanding places in our everyday lives. As citizens, we are asked to make decisions about social issues that involve science and technology. As workers, we have occupations that increasingly involve science and technology. In the 21st century, adults will need to be comfortable and competent in a complex, scientific and technological world. Schools have the responsibility of preparing students for the future. Schools must prepare all students — regardless of their future aspirations — to be scientifically literate.

Therefore, all graduates of our schools should be:

- ◆ knowledgeable about the important concepts and theories of the three major branches of scientific study: earth, life, and physical sciences;
- ◆ able to think scientifically and use scientific knowledge to make decisions about real-world problems;
- ◆ able to construct new knowledge for themselves through research, reading, and discussion;
- ◆ familiar with the natural world, and respectful of its unity, diversity, and fragility;
- ◆ able to make informed judgments on statements and debates claiming to have a scientific basis; and,
- ◆ able to reflect in an informed way on the role of science in human affairs.

To make this happen, education needs to:

1. emphasize understanding, not content coverage;
2. promote learning that is useful and relevant;
3. emphasize scientific literacy for ALL students; and,
4. promote interdisciplinary learning.

The “Michigan Content Standards and Benchmarks” describe three broad categories of activities that are common in scientifically literate individuals: **using** scientific knowledge; **constructing** new scientific knowledge, and **reflecting** on scientific knowledge. The content strands are directly related to these types of activities.

Vision Statement

Overview of the Science Content Strands

Strand I. Constructing New Scientific Knowledge

Scientifically literate students are learners as well as users of knowledge. With scientific literacy comes the ability to **ask questions** about the world that can be answered by using scientific knowledge and techniques. Scientifically literate students can also **develop solutions** to problems that they encounter or questions they ask. In developing solutions, scientifically literate students may use their own knowledge and reasoning abilities, seek out additional knowledge from other sources, and engage in empirical investigations of the real world. They can learn by **interpreting** text, graphs, tables, pictures, or other representations of scientific knowledge. Finally, scientifically literate students can remember key points and use sources of information to **reconstruct** previously learned knowledge, rather than try to remember every detail of what they study.

Standard I.1 Constructing New Scientific Knowledge

All students will ask questions that help them learn about the world; design and conduct investigations using appropriate methodology and technology; learn from books and other sources of information; communicate their findings using appropriate technology; and reconstruct previously learned knowledge.

There is one standard under Constructing New Scientific Knowledge. This standard incorporates the ways that scientists and individuals investigate and learn about the world.

Strand II. Reflecting on Scientific Knowledge

Scientifically literate students can also “step back” and analyze or reflect on their own knowledge. One important type of analysis is the **justification** of personal knowledge or beliefs using either theoretically or empirically based arguments. Scientifically literate students can also **show an appreciation** for scientific knowledge and the patterns that it reveals in the world; this often involves seeing **connections** among different areas of knowledge. They may be able to take a **historical and cultural perspective** on concepts and theories or to discuss institutional relationships among **science, technology, and society**. Finally, scientifically literate students can **describe the limitations** of their own knowledge and scientific knowledge in general.

Standard II.1 Reflecting on Scientific Knowledge

All students will analyze claims for their scientific merit and explain how scientists decide what constitutes scientific knowledge; how science is related to other ways of knowing; how science and technology affect our society; and how people of diverse cultures have contributed to and influenced developments in science.

There is one standard under Reflecting on Scientific Knowledge. This standard incorporates the nature of the

scientific enterprise, its strengths, limitations, and connections to other ways of knowing.

Strand III. Using Scientific Knowledge in Life Science

Scientifically literate students and adults can use their knowledge to understand the world around them and to guide their actions. Important types of activities that use scientific knowledge include **description** and **explanation** of real-world objects, systems, or events; **prediction** of future events or observations; and the **design** of systems or courses of action that enable people to adapt to and modify the world around them. In the life sciences, real-world contexts in which scientifically literate people use knowledge are often described in terms of **systems** and **subsystems**, such as cells, organisms, and ecosystems.

There are five standards under Using Scientific Knowledge in Life Science:

Standard III.1 Cells

All students will apply an understanding of cells to the functioning of multicellular organisms; and explain how cells grow, develop and reproduce.

Cells are the basic living unit of which all organisms are composed.

Standard III.2 The Organization of Living Things

All students will use classification systems to describe groups of living things; compare and contrast differences in the life cycles of living things; investigate and explain how living things obtain and use energy; and analyze how parts of living things are adapted to carry out specific functions.

Organization of living things occurs both across species (as in taxonomic organizations) and within organisms (their structures and processes).

Standard III.3 Heredity

All students will investigate and explain how characteristics of living things are passed on through generations; explain why organisms within a species are different from one another; and explain how new traits can be established by changing or manipulating genes.

Heredity is the means by which traits are transmitted from one generation to the next.

Standard III.4 Evolution

All students will explain how scientists construct and scientifically test theories concerning the origin of life and evolution of species; compare ways that living organisms are adapted (suited) to survive and reproduce in their environments; and analyze how species change through time.

Evolution explains the diversity of living things and the changes seen in them over time.

Standard III.5 Ecosystems

All students will explain how parts of an ecosystem are related and how they interact; explain how energy is distributed to living things in an ecosystem; investigate and explain how communities of living things change over a period of time; describe how materials cycle through an ecosystem and get reused in the environment; and analyze how humans and the environment interact.

It is within ecosystems that communities of living things interact.

Strand IV. Using Scientific Knowledge in Physical Science

*In the physical sciences, the specification of real-world contexts often focuses on **phenomena**, such as motion, electromagnetic interactions, or physical, chemical, and nuclear changes in matter.*

Four standards are under the broad heading of Using Scientific Knowledge in Physical Science:

Standard IV.1 Matter and Energy

All students will measure and describe the things around us; explain what the world around us is made of; identify and describe forms of energy; and explain how electricity and magnetism interact with matter.

Matter and energy are the fundamental entities of the physical universe.

Standard IV.2 Changes in Matter

All students will investigate, describe and analyze ways in which matter changes; describe how living things and human technology change matter and transform energy; explain how visible changes in matter are related to atoms and molecules; and how changes in matter are related to changes in energy.

Physical, chemical, and nuclear interactions of matter and energy bring about all of the changes we observe in the physical world.

Standard IV.3 Motion of Objects

All students will describe how things around us move and explain why things move as they do; demonstrate and explain how we control the motions of objects; and relate motion to energy and energy conversions.

Motion of objects is accounted for by gravitational, electromagnetic, and nuclear forces.

Standard IV.4 Waves and Vibrations

All students will describe sounds and sound waves; explain shadows, color, and other light phenomena; measure and describe vibrations and waves; and explain how waves and vibrations transfer energy.

Sound, light, and electromagnetic waves are the means by which energy and information are propagated.

Strand V. Using Scientific Knowledge in Earth Science

*In the earth sciences, real-world contexts are often described in terms of **systems** and **subsystems**, such as atmospheric systems, crustal systems, solar systems, or galaxies, which are useful in explaining **phenomena**, including volcanic eruptions, earthquakes, thunderstorms, and eclipses.*

Four standards are under the broad heading of Using Scientific Knowledge in Earth Science:

Standard V.1 The Geosphere

All students will describe the earth's surface; describe and explain how the earth's features change over time; and analyze effects of technology on the earth's surface and resources.

The geosphere includes earth's surface and geological processes.

Standard V.2 The Hydrosphere

All students will demonstrate where water is found on earth; describe the characteristics of water and how water moves; and analyze the interaction of human activities with the hydrosphere.

The Hydrosphere includes all forms of water. Of particular interest in Michigan is the water environment in the Great Lakes region.

Standard V.3 The Atmosphere and Weather

All students will investigate and describe what makes up weather and how it changes from day to day, from season to season and over long periods of time; explain what causes different kinds of weather; and analyze the relationships between human activities and the atmosphere.

Weather is composed of patterns of moisture, temperature and pressure which move through the atmosphere.

Standard V.4 The Solar System, Galaxy and Universe

All students will compare and contrast our planet and sun to other planets and star systems; describe and explain how objects in the solar system move; explain scientific theories as to the origin of the solar system; and explain how we learn about the universe.

We learn about neighboring and remote celestial bodies through our observations and exploration of space.

Note: Essays associated with each of these standards can be found in the 1991 publication *Michigan Essential Goals and Objectives for Science Education*, available from The Center for Career and Technical Education at Michigan State University, (800) 292-1606. Each essay describes how learners encounter the standard in real-world contexts, key characteristics of scientifically literate performance of the standard, and how, with successful teaching, learners' performance of the standard becomes more sophisticated over time.

Michigan Curriculum Framework Science Benchmarks

Approved Summer, 2000

Note: Newly written narratives for the Benchmarks are found in the MI BIG document at www.misd.net/mibig

MI BIG Science is a series of 15 narratives and articulated strand maps (with submaps) written to the 15 strands of the Michigan Curriculum Framework, Science Standards and Benchmarks (June 2000 version). MI BIG Science is a new way of looking at the entire content strand.

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Constructing New Scientific Knowledge (C) I.1

Elementary	Middle School	High School
All students will ask questions that help them learn about the world:		
<p>1. Generate questions about the world based on observation.</p> <p><i>Key concepts:</i> Questions lead to action, including careful observation and testing; questions often begin with “What happens if...?” or “How do these two things differ?”</p> <p><i>Real-world contexts:</i> Any in the sections on Using Scientific Knowledge.</p>	<p>1. Generate scientific questions about the world based on observation.</p> <p><i>Key concepts:</i> Scientific questions can be answered by gathering and analyzing evidence about the world.</p> <p><i>Real-world contexts:</i> Any in the sections on Using Scientific Knowledge.</p>	<p>1. Ask questions that can be investigated empirically.</p> <p><i>Key concepts:</i> Questions often build on existing knowledge.</p> <p><i>Real-world contexts:</i> Any in the sections on Using Scientific Knowledge.</p>
All students will design and conduct investigations using appropriate methodology and technology:		
<p>2. Develop solutions to problems through reasoning, observation, and investigations.</p> <p><i>Key concepts:</i> (K-2) gather information, ask questions, think; (3-5) observe, predict, collect data, draw conclusions, conduct fair tests; prior knowledge.</p> <p><i>Real-world contexts:</i> Any in the sections on Using Scientific Knowledge.</p>	<p>2. Design and conduct scientific investigations.</p> <p><i>Key concepts:</i> The process of scientific investigations—test, fair test, hypothesis, theory, evidence, observations, measurements, data, conclusion. Forms for recording and reporting data—tables, graphs, journals. See C-I.1 m.3 (tools).</p> <p><i>Real-world contexts:</i> Any in the sections on Using Scientific Knowledge; also, recognizing differences between observations and inferences; recording observations and measurements of everyday phenomena.</p>	<p>2. Design and conduct scientific investigations.</p> <p><i>Key concepts:</i> Types of scientific knowledge—hypothesis, theory, observation, conclusion, law, data, generalization. Aspects of field research—hypothesis, design, observations, samples, analysis, conclusion. Aspects of experimental research—hypothesis, design, variable, experimental group, control group, prediction, analysis, conclusion. Investigations are based on questions about the world (see C-I.1 h.1).</p> <p><i>Real-world contexts:</i> Any suggested in Using Scientific Knowledge benchmarks for which students would design and/or conduct investigations.</p>

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| <p>3. Manipulate simple devices that aid observation and data collection.</p> <p><i>Tools:</i> Various data collection tools suitable for this level, such as hand lenses, wind direction indicators, grids for sampling areas of the sky or landscape.</p> <p><i>Real-world contexts:</i> Any suggested in Using Scientific Knowledge benchmarks for which students would design and/or conduct investigations.</p> | <p>3. Use tools and equipment appropriate to scientific investigations.</p> <p><i>Tools:</i> various data collection tools suitable for this level, including computers.</p> <p><i>Real-world contexts:</i> Any suggested in Using Scientific Knowledge benchmarks for which students would design and/or conduct investigations.</p> | |
| <p>4. Use simple measurement devices to make measurements in scientific investigations.</p> <p><i>Key concepts:</i> Measurement units—milliliters, liters, teaspoon, tablespoon, ounce, cup, millimeter, centimeter, meter, gram.</p> <p><i>Measurement tools:</i> Measuring cups and spoons, measuring tape, scale, thermometer, rulers, graduated cylinders.</p> <p><i>Real-world contexts:</i> Making simple mixtures, such as food, play dough, papier mache; measuring height of a person, weight of a ball.</p> | <p>4. Use metric measurement devices to provide consistency in an investigation.</p> <p><i>Key concepts:</i> Documentation—laboratory instructions. Measurement units—milliliters, liters, millimeter, centimeter, meter, gram.</p> <p><i>Measurement tools:</i> Balancing devices, measuring tape, thermometer, graduated cylinder.</p> <p><i>Real-world contexts:</i> Conducting investigations, following or altering laboratory instructions for mixing chemicals.</p> | <p>3. Recognize and explain the limitations of measuring devices.</p> <p><i>Key concepts:</i> Uncertainty, error, range, tolerances, accuracy, precision.</p> <p><i>Tools:</i> Balance, thermometer, measuring tape, ruler, graduated cylinder, electronic measuring devices.</p> <p><i>Real-world contexts:</i> Experiments that use quantitative data; manufacturing systems where measurements are critical.</p> |
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All students will learn from books and other sources of information:

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| <p>5. Develop strategies and skills for information gathering and problem solving.</p> <p><i>Tools:</i> Sources of information, such as reference books, trade books, magazines, web sites, other people's knowledge.</p> <p><i>Real-world contexts:</i> Seeking help from or interviewing peers, adults, experts; using libraries, World Wide Web, CD-ROMs and other computer software, other resources.</p> | <p>5. Use sources of information in support of scientific investigations.</p> <p><i>Tools:</i> Periodicals, reference books, trade books, web sites, computer software; forms for presenting scientific information, such as figures, tables, graphs. See R-II.1 m.1 (evaluate strengths/weaknesses of claims).</p> <p><i>Real-world contexts:</i> Libraries, projects where research is needed.</p> | <p>4. Gather and synthesize information from books and other sources of information.</p> <p><i>Key concepts:</i> Scientific journals, text- and computer-based reference materials.</p> <p><i>Real-world contexts:</i> Libraries, technical reference books, Internet, computer software.</p> |
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All students will communicate findings of investigations, using appropriate technology.

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| <p>6. Construct charts and graphs and prepare summaries of observations.</p> <p><i>Key concepts:</i> Increase, decrease, no change, bar graph, data table.</p> <p><i>Tools:</i> Graph paper, rulers, crayons.</p> <p><i>Real-world contexts:</i> Examples of bar charts like those found in a newspaper.</p> | <p>6. Write and follow procedures in the form of step-by-step instructions, formulas, flow diagrams, and sketches.</p> <p><i>Key concepts:</i> Purpose, procedure, observation, conclusion, data.</p> <p><i>Real-world contexts:</i> Listing or creating the directions for completing a task, reporting on investigations.</p> | <p>5. Discuss topics in groups by making clear presentations, restating or summarizing what others have said, asking for clarification or elaboration, taking alternative perspectives, and defending a position.</p> <p><i>Key concepts:</i> Logical argument, summary, clarification, elaboration, alternative perspectives.</p> <p><i>Real-world contexts:</i> Newspaper or magazine articles discussing a topic of social concern.</p> |
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Reflecting on Scientific Knowledge (R) II.1

Elementary	Middle School	High School
All students will analyze claims for their scientific merit and explain how scientists decide what constitutes scientific knowledge:		
<p>1. Develop an awareness of the need for evidence in making decisions scientifically.</p> <p><i>Key concepts:</i> (K-2) observations; (3-5) data, evidence, sample, fact, opinion.</p> <p><i>Real-world contexts:</i> Deciding whether an explanation is supported by evidence in simple experiments, or relies on personal opinion.</p>	<p>1. Evaluate the strengths and weaknesses of claims, arguments, or data.</p> <p><i>Key concepts:</i> Aspects of arguments such as data, evidence, sampling, alternate explanation, conclusion; inference, observation.</p> <p><i>Real-world contexts:</i> Deciding between alternate explanations or plans for solving problems; evaluating advertising claims or cases made by interest groups; evaluating sources of references.</p> <p>2. Describe limitations in personal knowledge.</p> <p><i>Key concepts:</i> Recognizing degrees of confidence in ideas or knowledge from different sources, evaluating dates and sources of references.</p> <p><i>Real-world contexts:</i> Any in the sections on Using Scientific Knowledge.</p>	<p>1. Justify plans or explanations on a theoretical or empirical basis.</p> <p><i>Key concepts:</i> Aspects of logical argument, including evidence, fact, opinion, assumptions, claims, conclusions, observations.</p> <p><i>Real-world contexts:</i> Any in the sections on Using Scientific Knowledge.</p> <p>2. Describe some general limitations of scientific knowledge.</p> <p><i>Key concepts:</i> Understanding of the general limits of science and scientific knowledge as constantly developing human enterprises; recognizing that arguments can have emotive, economic, and political dimensions as well as scientific.</p> <p><i>Real-world contexts:</i> Any in the sections on Using Scientific Knowledge.</p>
All students will show how science is related to other ways of knowing:		
<p>2. Show how science concepts can be illustrated through creative expression such as language arts and fine arts.</p> <p><i>Key concepts:</i> Poetry, expository work, painting, drawing, music, diagrams, graphs, charts.</p> <p><i>Real-world contexts:</i> Explaining simple experiments using paintings and drawings; describing natural phenomena scientifically and poetically.</p>	<p>3. Show how common themes of science, mathematics, and technology apply in real-world contexts.</p> <p><i>Thematic ideas:</i> Systems-subsystems, feedback models, mathematical constancy, scale, conservation, structure, function, adaptation.</p> <p><i>Real-world contexts:</i> Any in the sections on Using Scientific Knowledge.</p>	<p>3. Show how common themes of science, mathematics, and technology apply in real-world contexts.</p> <p><i>Thematic ideas:</i> Systems-subsystems, feedback models, mathematical constancy, scale, conservation, structure, function, adaptation.</p> <p><i>Real-world contexts:</i> Any in the sections on Using Scientific Knowledge.</p>

4. Discuss the historical development of key scientific concepts and principles.

Key concepts: Historical, political, social, and economic factors influencing the development of science. See *Benchmarks for Science Literacy*, AAAS, Chapter 10.

Real-world contexts: Historical development of key scientific theories.

All students will show how science and technology affect our society:

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| <p>3. Describe ways in which technology is used in everyday life.</p> <p><i>Key concepts:</i> Provide faster and farther transportation and communication, organize information and solves problems, save time.</p> <p><i>Real-world contexts:</i> Cars, other machines, radios, telephones, computer games, calculators, appliances, e-mail, the World Wide Web.</p> | <p>4. Describe the advantages and risks of new technologies.</p> <p><i>Key concepts:</i> Risk, benefit, side effect, advantage, disadvantage.</p> <p><i>Real-world contexts:</i> Technological systems for manufacturing, transportation, energy distribution, housing, medicine (such as cloning, genetic engineering).</p> | <p>5. Explain the social and economic advantages and risks of new technology.</p> <p><i>Key concepts:</i> Cost-benefit analysis; See LO h.5 (health technology), PME-IV.1 h.1 (household and agricultural materials, EG-V.1 h.4 (resource use), LEC-III.5 h.6 (effects of urban development and agriculture on ecosystems), EAW-V.3 h.4 (air pollution), EH-V.2 h.2 (water pollution.)</p> <p><i>Real-world contexts:</i> Issues related to new technologies, including ones in health-care, transportation, communications, manufacturing, information and media.</p> |
| <p>4. Develop an awareness of and sensitivity to the natural world.</p> <p><i>Key concepts:</i> Appreciation of the balance of nature and the effects organisms have on each other, including the effects humans have on the natural world.</p> <p><i>Real-world contexts:</i> Any in the sections on Using Scientific Knowledge appropriate to elementary school.</p> | <p>5. Develop an awareness of and sensitivity to the natural world.</p> <p><i>Key concepts:</i> Appreciation of the balance of nature and the effects organisms have on each other, including the effects humans have on the natural world.</p> <p><i>Real-world contexts:</i> Any in the sections on Using Scientific Knowledge appropriate to middle school.</p> | <p>6. Develop an awareness of and sensitivity to the natural world.</p> <p><i>Key concepts:</i> Appreciation of the balance of nature and the effects organisms have on each other, including the effects humans have on the natural world.</p> <p><i>Real-world contexts:</i> Any in the sections on Using Scientific Knowledge appropriate to high school.</p> |

All students will show how people of diverse cultures have contributed to and influenced developments in science:

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| 5. Develop an awareness of contributions made to science by people of diverse backgrounds and cultures.

<i>Key concepts:</i> Scientific contributions made by people of diverse cultures and backgrounds.

<i>Real-world contexts:</i> Any in the sections on Using Scientific Knowledge appropriate to this benchmark. | 6. Recognize the contributions made in science by cultures and individuals of diverse backgrounds.

<i>Key concepts:</i> Cultural contributions to science, contributions made by people of diverse backgrounds.

<i>Real-world contexts:</i> Biographies of minority and female scientists; histories of cultural contributions to science. | 7. Describe the historical, political, and social factors affecting developments in science.

<i>Key concepts:</i> Historical, political, social, and economic factors influencing the development of science.

<i>Real-world contexts:</i> The development of the sun-centered model of the solar system and political pressures on Galileo; the development of Darwin's theory of evolution by natural selection. |
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Cells (LC) III.1

Elementary	Middle School	High School
All students will apply an understanding of cells to the functioning of multicellular organisms, including how cells grow, develop and reproduce:		
(No benchmark about cells at the elementary level)	<p>1. Demonstrate evidence that all parts of living things are made of cells.</p> <p><i>Key concepts:</i> Types of living things: plants, animals; parts of organisms: tissues, organs, organ systems; all functions of organisms are carried out by cells. See LC-III.1 m.2 for specific functions.</p> <p><i>Tools:</i> Hand lens, microscope.</p> <p><i>Real-world contexts:</i> Common plant or animal cells: Elodea leaf cells, onion skin cells, human cheek cells. Single-celled organisms: Paramecium.</p> <p>2. Explain why and how selected specialized cells are needed by plants and animals.</p> <p><i>Key concepts:</i> Specialized functions of cells—reproduction, photosynthesis, transport, movement, disease-fighting. See LO m.4 (systems and processes functioning to provide/remove materials to/from cells).</p> <p><i>Real-world contexts:</i> Specialized animal cells: red blood cells, white blood cells, muscle cells, bone cells, nerve cells, egg/sperm cells; specialized plant cells—root cells, leaf cells, stem cells.</p>	<p>1. Explain how multicellular organisms grow, based on how cells grow and reproduce.</p> <p><i>Key concepts:</i> Specialized functions of cells—respiration (see LO h.3), protein synthesis, mitosis, meiosis (see LH-III.3 h.2). Basic molecules for cell growth—simple sugars, amino acids, fatty acids. Basic chemicals, molecules and atoms—water, minerals, carbohydrates, proteins, fats and lipids, nucleic acids; carbon, hydrogen, oxygen, nitrogen. Cells come only from other cells. See LO m.4 (digestion).</p> <p><i>Real-world contexts:</i> The growth of plants and animals.</p> <p>2. Compare and contrast ways in which selected cells are specialized to carry out particular life functions.</p> <p><i>Key concepts:</i> Classifications of organisms by cell type—plant, animal, bacteria; selected specialized plant and animal cells—red blood cells, white blood cells, muscle cells, nerve cells, root cells, leaf cells, stem cells; cell parts used for classification — organelle, nucleus, cell wall, cell membrane; specialized functions — reproduction (see LC-III.1 h.1, LH-III.3 h.2), photosynthesis (see LO m.3), transport; cell shape.</p> <p><i>Tools:</i> microscopes</p> <p><i>Real-world contexts:</i> Reproduction, growth, response, movement, etc. of animals and plants. Functions of bacteria.</p>

Organization of Living Things (LO) III.2

Elementary	Middle School	High School
All students will use classification systems to describe groups of living things:		
<p>1. Explain characteristics and functions of observable body parts in a variety of animals.</p> <p><i>Key concepts:</i> Observable characteristics—fur, scales, feathers, horns, claws, eyes, quills, beaks, teeth, skeleton, muscles, exoskeleton; functions—insulation, support, movement, food-getting, protection.</p> <p><i>Real-world contexts:</i> Vertebrate and invertebrate animals, such as humans, cows, sparrows, goldfish, spiders, crayfish, insects.</p> <p>2. Compare and contrast (K-2) or classify (3-5) familiar organisms on the basis of observable physical characteristics.</p> <p><i>Key concepts:</i> Plant and animal parts—backbone, skin, shell, limbs, roots, leaves, stems, flowers, feathers, scales.</p> <p><i>Real-world contexts:</i> Animals that look similar—snakes, worms, millipedes; flowering and nonflowering plants; pine tree, oak tree, rose, algae.</p>	<p>1. Compare and classify organisms into major groups on the basis of their structure.</p> <p><i>Key concepts:</i> Characteristics used for classification—vertebrates/ invertebrates, cold-blooded/warm-blooded, single-cell/multicellular, flowering/nonflowering; groups of vertebrates—mammals, birds, fish, reptiles, amphibians.</p> <p><i>Observation tools:</i> Hand lens, microscope.</p> <p><i>Real-world contexts:</i> Representative organisms, such as dog, worm, snake, Amoeba, geranium, bacterium, insect, mold.</p>	<p>1. Classify major groups of organisms to the kingdom level.</p> <p><i>Key concepts:</i> Kingdom categories—protist, fungi, moneran, animal, plant. Characteristics for classification—cell wall, cell membrane, organelle, single-celled, multicellular.</p> <p><i>Real-world contexts:</i> Common local representatives of each of the five major kingdoms—Paramecium, yeast, mushroom, bacteria, frog, geranium.</p>

All students will compare and contrast differences in the life cycles of living things:

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| <p>3. Describe life cycles of familiar organisms.</p> <p><i>Key concepts:</i> Life cycle stages—egg, young, adult; seed, plant, flower, fruit; larva, pupa.</p> <p><i>Real-world contexts:</i> Common plants and animals such as bean plants, apple trees, butterflies, grasshoppers frogs, birds.</p> | <p>2. Describe the life cycle of a flowering plant.</p> <p><i>Key concepts:</i> Flowering plant parts and processes—roots, stems, leaves, flowers, fruits, seeds, embryo, pollen, ovary, egg cell, germination, fertilization.</p> <p><i>Tools:</i> Microscope, hand lens.</p> <p><i>Real-world contexts:</i> Common flowering plants, such as bean, tulip.</p> | <p>2. Describe the life cycle of an organism associated with human disease.</p> <p><i>Key concepts:</i> Infection process—disease, parasite, carrier, host, infection.</p> <p><i>Tools:</i> Microscope, hand lens.</p> <p><i>Real-world contexts:</i> Life cycle of organism(s) associated with human disease(s), such as Lyme disease—tick, malaria—mosquito, parasites.</p> |
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All students will investigate and explain how living things obtain and use energy:

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| <p>4. Compare and contrast food, energy, and environmental needs of selected organisms.</p> <p><i>Key concepts:</i> Life requirements—food, air, water, minerals, sunlight, space, habitat. See LEC-III.5 e.2.</p> <p><i>Real-world contexts:</i> Germinating seeds, such as beans, corn; aquarium or terrarium life, such as guppy, goldfish, snail.</p> | <p>3. Describe evidence that plants make and store food.</p> <p><i>Key concepts:</i> Process and products of food production and transport—photosynthesis, starch, sugar, oxygen, carbon dioxide, water. See LO m.4 (use of food for energy.)</p> <p><i>Real-world contexts:</i> Plant food storage organs, such as potato, onion; starch storage in plants grown under different conditions.</p> | <p>3. Explain the process of food storage and food use in organisms.</p> <p><i>Key concepts:</i> Cellular respiration, photosynthesis (see LO m.3), oxygen, sunlight, carbon dioxide, carbohydrate, fat, protein, minerals, water. See LC-III.1 h.1 (how organisms grow), LO-III.2 m.3 (how plants store food) LO-III.2 m.4 (how food and oxygen are distributed to cells), LEC-III.5 m.2 (the sun as the ultimate source of energy for organisms) and PCM-IV.2 m.3 (energy transformations).</p> <p><i>Real-world contexts:</i> Food storage, such as maple tree—maple sap, potato—starch, honey bee—honey, cow—beef, milk. Weight gain and weight loss. Change in respiration rates with exercise.</p> |
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All students will analyze how parts of living things are adapted to carry out specific functions:

5. Explain functions of selected seed plant parts.

Key concepts: Plant parts—roots, stems, leaves, flowers, fruits, seeds.

Real-world contexts: Common edible plant parts, such as bean, cauliflower, carrot, apple, tomato, spinach.

(See LE-III.4 e.2 about functions of selected animal body parts.)

4. Explain how selected systems and processes work together in animals.

Key concepts: Systems/Processes—digestion, circulation, respiration, endocrine, reproduction, skeletal, muscular, nervous, excretion, transport, growth, repair.

Real-world contexts: Interrelations of body systems during selected activities, such as among skeletal, muscular, circulatory, and respiratory systems during physical exercise.

4. Explain how living things maintain a stable internal environment.

Key concepts: Related systems/cells/ chemicals—excretory system, endocrine system, circulatory system, hormones, immune response, white blood cell, bacteria, virus. Factors/ mechanisms under control—temperature, disease/infection, homeostasis.

Real-world contexts: Mechanisms for maintaining internal stability, such as body temperature, disease control.

5. Describe technology used in the prevention, diagnosis, and treatment of diseases and explain its function in terms of human body processes.

Key concepts: Available technologies—sanitation, adequate food and water supplies, inoculation, antibodies, biochemistry, medicines, organ transplants. (See PWV-IV.4 h.4, ultrasound/x-ray.)

Real-world contexts: Common contexts for these technologies—health maintenance and disease prevention activities, such as exercise and controlled diets; health monitoring activities, such as cholesterol and blood pressure checks and various tests for cancer.

Heredity (LH) III.3

Elementary	Middle School	High School
All students will investigate and explain how characteristics of living things are passed on through generations:		
<p>1. Give evidence that characteristics are passed from parents to young.</p> <p><i>Key concepts:</i> Characteristics—hair and feather color, eye color, leaf shape, flower structure.</p> <p><i>Real-world contexts:</i> Example of mature and immature organisms, such as dogs/puppies, cats/kittens, maple trees/saplings, beans/seedlings.</p>	<p>1. Describe how the characteristics of living things are passed on through generations.</p> <p><i>Key concepts:</i> Reproductive cells—egg, sperm. Chromosome, gene, hereditary information.</p> <p><i>Real-world contexts:</i> Common traits controlled by a single gene pair, such as wrinkled or smooth seeds in a pea plant, color of horse hair; human traits such as tongue rolling.</p>	<p>1. Explain how characteristics of living things are passed on from generation to generation.</p> <p><i>Key concepts:</i> Traits—dominant, recessive. Genetic material—gene pair, gene combination, gene sorting.</p> <p><i>Real-world contexts:</i> Common contexts—inheritance of a human genetic disease/disorder, such as sickle cell anemia; a family tree focused on certain traits; examining animal or plant pedigrees.</p>
All students will explain why organisms within a species are different from one another:		
<p>(No corresponding benchmark at this level.)</p>	<p>2. Describe how heredity and environment may influence/determine characteristics of an organism.</p> <p><i>Key concepts:</i> Traits—inherited, acquired.</p> <p><i>Real-world contexts:</i> Data on heredity, such as identical twin studies, effects of introduced toxins, effects of natural selection, effects of controlled selection and breeding.</p>	<p>2. Describe how genetic material is passed from parent to young during sexual and asexual reproduction.</p> <p><i>Key concepts:</i> Types of cell division—mitosis, meiosis. DNA replication, chromosome. Types of reproduction—sexual, asexual. Genetic variation.</p> <p><i>Tools:</i> A-V media, diagrams showing DNA replication during cell division.</p> <p><i>Real-world contexts:</i> Fruit flies, yeast, reproduction by spores, cloning.</p>

All students will explain how new traits can be established by changing or manipulating genes:

(No corresponding benchmark at this level.)

(No corresponding benchmark at this level.)

3. Explain how new traits may arise in individuals through changes in genetic material (DNA).

Key concepts: Genetic changes—variation, new gene combinations, mutation. Natural and human-produced sources of mutation—radiation, chemicals. See LE-III.4 m.2 (how new traits become established in populations.)

Real-world contexts: Products of genetic engineering, such as medical advances—insulin, cancer drugs; agricultural related products, such as navel oranges, new flower colors, higher-yield grains; effects of natural and man-made contamination; examples of variations due to new gene combinations, such as hybrid organisms or new plant varieties resulting from multiple sets of genes.

Evolution (LE) III.4

Elementary	Middle School	High School
All students will explain how scientists construct and scientifically test theories concerning the origin of life and evolution of species:		
<p>1. Explain how fossils provide evidence about the nature of ancient life.</p> <p><i>Key concepts:</i> Types of evidence—fossil, extinct, ancient, modern life forms. See EG-V.1 e.4 (rocks and fossils provide evidence of history of the earth).</p> <p><i>Real-world contexts:</i> Common contexts—plant and animal fossils, museum dioramas and paintings/drawings of ancient life and/or habitats.</p>	<p>1. Describe how scientific theory traces possible evolutionary relationships among present and past life forms.</p> <p><i>Key concepts:</i> Selected evidence of common ancestry—geologic time, fossil, bone, embryo, limb.</p> <p><i>Real-world contexts:</i> Fossils that show evidence of common ancestry, such as similarity of vertebrate limb bones, similarity of early vertebrate embryos, similarity of fossil bones to those of contemporary animals i.e., horse legs.</p>	<p>1. Describe what biologists consider to be evidence for human evolutionary relationships to selected animal groups.</p> <p><i>Key concepts:</i> Common types of evidence used—hominid fossils, vestigial structures, DNA, protein structure.</p> <p><i>Real-world contexts:</i> Skeletal comparisons, such as modern human to hominid fossils; anatomical and biochemical similarities of humans and other higher primates, such as blood proteins; similarity of early human embryo stages to those of other vertebrates; vestigial structures, such as appendix, tail bone.</p>
All students will compare ways that living organisms are adapted (suited) to survive and reproduce in their environments and explain how species change through time:		
<p>2. Explain how physical and behavioral characteristics of animals help them to survive in their environments.</p> <p><i>Key concepts:</i> Characteristics—adaptation, instinct, learning, habit. Traits and their adaptive values—sharp teeth or claws for catching and killing prey, color for camouflage, behaviors.</p> <p><i>Real-world contexts:</i> Common vertebrate adaptations, such as white polar bears, sharp claws and sharp canines for predators, changing colors of chameleon; behaviors, such as migration, communication of danger.</p>	<p>2. Explain how new traits might become established in a population and how species become extinct.</p> <p><i>Key concepts:</i> Environmental change, variation in populations, reproductive success.</p> <p><i>Real-world contexts:</i> Examples of inheritable and non-inheritable variations, such as white-eyed fruit fly or scars; examples of variations due to new gene combinations, such as hybrid organisms.</p>	<p>2. Explain how a new species or variety may originate through the evolutionary process of natural selection.</p> <p><i>Key concepts:</i> Concept of species; how new species or varieties are established—natural selection, inheritable, non-inheritable characteristics, species variation.</p> <p><i>Real-world contexts:</i> Contemporary examples of natural selection, such as bacteria resistance to antibiotics, insect resistance to pesticides; examples of artificial selection, such as agricultural selection to increase production, selecting desired traits for pets; historical examples of naïve explanations of evolution, such as the Lamarkian explanation of the evolution of the giraffe's long neck.</p>

Ecosystems (LEC) III.5

Elementary	Middle School	High School
All students will explain how parts of an ecosystem are related and how they interact:		
<p>1. Identify familiar organisms as part of a food chain or food web and describe their feeding relationships within the web.</p> <p><i>Key concepts:</i> Producer, consumer, predator, prey, decomposer, habitat, community.</p> <p><i>Real-world contexts:</i> Food chains and food webs involving organisms, such as rabbits, birds, snakes, grasshoppers, plants.</p>	<p>1. Describe common patterns of relationships among populations.</p> <p><i>Key concepts:</i> Participants and relationships—predator, prey, parasite, competition, mutually beneficial.</p> <p><i>Real-world contexts:</i> Relationships among plants and animals in an ecosystem—mutually helpful relationships, such as insects and flowering plants, birds eating fruit and spreading seeds; parasitic (harmful) relationships, such as humans and mosquitoes, trees and mistletoe; competitive relationships, including squirrels and seed-eating birds, weeds and garden plants.</p>	<p>1. Describe common ecological relationships between and among species and their environments.</p> <p><i>Key concepts:</i> Competition, territory, carrying capacity, natural balance, population, dependence, survival; biotic, abiotic factors.</p> <p><i>Real-world contexts:</i> Animals that live in packs or herds and plant colonies, such as—wolves, bison, lilies and other bulb plants, various forms of algae.</p>
All students will explain how energy is distributed to living things in an ecosystem:		
<p>2. Describe the basic requirements for all living things to maintain their existence.</p> <p><i>Key concepts:</i> Needs of life—food, habitat, water, shelter, air, light, minerals. See LO-III.2 e.4.</p> <p><i>Real-world contexts:</i> Selected ecosystems, such as an aquarium, rotting log, terrarium, backyard, local pond or wetland, wood lot.</p>	<p>2. Describe how organisms acquire energy directly or indirectly from sunlight.</p> <p><i>Key concepts:</i> Sunlight, plants, food, photosynthesis, producers, consumers, food webs. See LO-III.2 m.3 (photosynthesis and food use).</p> <p><i>Real-world contexts:</i> Selected food webs, including humans.</p>	<p>2. Explain how energy flows through familiar ecosystems.</p> <p><i>Key concepts:</i> Participants and relationships—food chain, food web, energy pyramid, energy flow, producers, consumers, decomposers. See LO-III.2 m.3 (producers), PCM-IV.2 h.4 (conservation of energy).</p> <p><i>Real-world contexts:</i> Energy pyramids for food webs in various ecosystems.</p>

All students will investigate and explain how communities of living things change over a period of time:

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| <p>3. Design systems that encourage growing of particular plants or animals.</p> <p><i>Key concepts:</i> Needs of life—food, habitat, water, shelter, air, light, minerals.</p> <p><i>Real-world contexts:</i> Ecosystems managed by humans, including farms, ranches, gardens, lawns, potted plants.</p> | <p>3. Predict the effects of changes in one population in a food web on other populations.</p> <p><i>Key concepts:</i> Natural balance, population, dependence, survival, community, biodiversity, introduction of non-native species.</p> <p><i>Real-world contexts:</i> Plants and animals in an ecosystem dependent upon each other for survival in selected ecosystems—see LEC-III.5 e.2; comparison of animals and plants found in polluted vs. nonpolluted water, urban vs. rural settings, rural vs. forest settings; zebra mussels introduced into the Great Lakes, gypsy moths defoliating trees.</p> | <p>3. Describe general factors regulating population size in ecosystems.</p> <p><i>Key concepts:</i> Carrying capacity, competition, parasitism, predation, loss of habitat.</p> <p><i>Real-world contexts:</i> Common factors that influence relationships, such as weather, disease, predation, migration.</p> |
| | <p>4. Describe the likely succession of a given ecosystem over time.</p> <p><i>Key concepts:</i> Succession, stages, climax community, pioneer.</p> <p><i>Real-world contexts:</i> Process of gradual change in ecological systems, such as in ponds or abandoned farm fields.</p> | <p>4. Describe responses of an ecosystem to events that cause it to change.</p> <p><i>Key concepts:</i> Succession, pioneer, climate/physical conditions, introduction of new/different species, elimination of existing species, biodiversity; cataclysmic changes.</p> <p><i>Real-world contexts:</i> Climax forests comprised of maple, beech, or conifers; effects of urban sprawl or clear cutting forests; effects of cataclysmic changes such as the eruption of Mt. St. Helens.</p> |

All students will describe how materials cycle through an ecosystem and get reused in the environment:

(No corresponding benchmark at this level)

(No corresponding benchmark at this level)

5. Describe how carbon and soil nutrients cycle through selected ecosystems.

Key concepts: Common nutrients/elements — nitrogen, sulfur, carbon, phosphorous. Inorganic compounds containing nutrients—soil minerals, carbon dioxide. Organic compounds in living communities—proteins, fats, carbohydrates. See LO-III.2 h.3 (cell respiration) and LO-III.2 m.3 (photosynthesis).

Real-world contexts: Movement of food materials through various foodwebs, including decomposition.

All students will analyze how humans and the environment interact:

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| <p>4. Describe positive and negative effects of humans on the environment.</p> <p><i>Key concepts:</i> Human effects on the environment—garbage, habitat destruction, land management, renewable and non-renewable resources.</p> <p><i>Real-world contexts:</i> Household wastes, school wastes, waste water treatment, habitat destruction due to community growth, reforestation projects, establishing parks or other green spaces, recycling.</p> | <p>5. Explain how humans use and benefit from plant and animal materials.</p> <p><i>Key concepts:</i> Materials from plants, including—wood, paper, cotton, linen, starch, rubber, wax, and oils. Materials from animals, including leather, wool, fur, oils, wax.</p> <p><i>Real-world contexts:</i> Human-made objects that incorporate plant and animal materials, including clothing, building materials, machines, and medicines.</p> | <p>6. Explain the effects of agriculture and urban development on selected ecosystems.</p> <p><i>Key concepts:</i> Common factors that influence ecosystems, such as pollution of ecosystems from fertilizer, insecticide, and other chemicals. Land management, biodiversity, sustainability. Loss of habitat. See PME-IV.1 h.1 (risk/benefit analysis), EH-V.2 h.2 (water pollution).</p> <p><i>Real-world contexts:</i> Common factors that influence ecosystems, such as pollution of ecosystems from fertilizer, insecticide, and other chemicals.</p> |
| <p>6. Describe ways in which humans alter the environment.</p> <p><i>Key concepts:</i> Agriculture, land use, renewable and non-renewable resource development, resource use, solid waste, toxic waste. Biodiversity. See EG-V.1 m.5, EH-V.2 m.3, EAW-V.3 m.4.</p> <p><i>Real-world contexts:</i> Human activities, such as farming, pollution from manufacturing and other sources, hunting, habitat destruction, land development, reforestation, species reintroduction.</p> | | |

Matter and Energy (PME) IV.1

Elementary

Middle School

High School

All students will measure and describe the things around us:

1. Classify common objects and substances according to observable attributes/properties.

Key concepts: Texture—rough, smooth. Flexibility—rigid, stiff, firm, flexible, strong. Hardness. Smell—pleasant, unpleasant. States of matter—solid, liquid, gas. Magnetic properties—attract, repel, push, pull. Size—larger, smaller (K-2); length, width, height (3-5). Sink, float. Color—common color words. Shape—circle, square, triangle, rectangle, oval. Weight—heavy, light, heavier, lighter. See PWV-IV.4 e.4 (shadows: objects that let light pass through or block light); PME-IV.1 e.2 (materials that conduct electricity); C-I.1 e.4 (use measuring devices).

Real-world contexts: Common objects, such as desks, coins, pencils, buildings, snowflakes; common substances, including—solids, such as copper, iron, wood, plastic, Styrofoam; liquids, such as water, alcohol, milk, juice; gases such as air, helium, water vapor.

2. Identify properties of materials which make them useful.

Key concepts: Useful properties—unbreakable, water-proof, light-weight, conducts electricity (see PME-IV.1 e.4, electric circuits), conducts heat, attracted to a magnet, clear. See EG-V.1 e.4 (uses of earth materials).

Real-world contexts: Appropriate selection of materials for a particular use, such as waterproof raincoat, cotton or wool for clothing, glass for windows, metal pan to conduct heat, copper wire to conduct electricity.

1. Describe and compare objects in terms of mass, volume, and density.

Key concepts: Units of density—grams per cubic centimeter or grams per milliliter.

Measurement tools: Balance, measuring cup or graduated cylinder, metric ruler. See C-I.1 m.4 (making measurements).

Real-world contexts: Common objects and substances.

2. Explain when length, mass, weight, density, area, volume or temperature are appropriate to describe the properties of an object or substance.

Key concepts: Appropriate metric (s.i.) units. See C-I.1 m.4 (use measuring devices).

Measurement tools: Balances, spring scales, measuring cups or graduated cylinders, thermometers, metric ruler.

Real-world contexts: Common substances such as those listed in PME-IV.1 e.1; hot and cold substances, such as ice, snow, cold water, hot water, steam, cold air, hot air.

1. Analyze properties of common household and agricultural materials in terms of risk/benefit balance.

Key concepts: Risk/benefit analysis.

Real-world contexts: Herbicides, refrigerants, fertilizers, detergents.

2. Identify properties of common families of elements.

Key concepts: Properties—state, reactivity, metal/non-metal, conductivity.

Tools: Various element samples.

Real-world contexts: Highly reactive metals (such as potassium, sodium), less-reactive metals (such as calcium), highly reactive nonmetals (such as chlorine, fluorine, and oxygen), almost completely nonreactive gases (such as helium and neon); relationships on the Periodic Table of Elements.

All students will explain what the world around us is made of:

(No elementary benchmark about molecules or atoms)

3. Classify substances as elements, compounds, or mixtures and justify classifications in terms of atoms and molecules.

Key concepts: Element, compound, mixture, molecule, atom. See PME-IV.1 m.4 (molecular structure of solids, liquids and gases).

Real-world contexts: Common substances such as those listed above, including—elements, such as copper, aluminum, sulfur, helium, iron; compounds, such as water, salt, sugar, carbon dioxide; mixtures, such as soil, salt and pepper, salt water, air.

4. Describe the arrangement and motion of molecules in solids, liquids, and gases.

Key concepts: Arrangement—regular pattern, random. Distance between molecules—closely packed, separated. Molecular motion—vibrating, bumping together, moving freely. (PCM-IV.2 m.4 addresses the molecular explanations of changes of state.)

Real-world contexts: Common solids, liquids, and gases, such as those listed above.

3. Explain how elements differ, in terms of the structural parts and electrical charges of atoms.

Key concepts: Parts of atoms—nucleus, electron cloud. Subatomic particles—proton, neutron, electron. Electrical charges—positive, negative, neutral. Each element has a unique number of protons. See PMO-IV.3 m.3 (electric force).

Real-world contexts: All elements.

All students will identify and describe forms of energy:

3. Identify forms of energy associated with common phenomena.

(Benchmarks about energy are in other strands at the middle school level.)

(Benchmarks about energy are in other strands at the high school level.)

Key concepts: Heat, light, sound, food energy, energy of motion, electricity (see PCM-IV.2 e.1 about heat, PWV-IV.4 e.1-4 about light and sound, PME-IV.1 e.4 about electricity, LEC-III.5 e.2 about energy from food).

Real-world contexts: Appropriate selection of energy and phenomena, such as appliances like a toaster or iron that use electricity, sun's heat to melt chocolate, water wheels, wind-up toys, warmth of sun on skin, windmills, music from guitar, simple electrical circuits with batteries, bulbs and bells.

All students will explain how electricity (and magnetism; see PMO) interact with matter:

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| <p>4. Construct simple, useful electrical circuits. (3-5)</p> <p><i>Key concepts and tools:</i> Complete loop; batteries, bulbs, bells, motors, wires, electrical switches (see PME-IV.1 e.2, materials that conduct electricity).</p> <p><i>Real-world contexts:</i> Flashlights, battery-powered toys.</p> | <p>5. Construct simple circuits and explain how they work in terms of the flow of current.</p> <p><i>Key concepts and tools:</i> Complete circuit, incomplete circuit, short circuit, current, conductors, non-conductors, batteries, household current, bulbs, bells, motors, electrical switches.</p> <p><i>Real-world contexts:</i> Household wiring, electrical conductivity testing, electric appliances.</p> | <p>4. Explain how current is controlled in simple series and parallel circuits.</p> <p><i>Key concepts:</i> Single path, multiple paths, switches, fuses, circuit breakers, power supply, batteries, household current, motors, bulbs, circuit diagrams.</p> <p><i>Real-world contexts:</i> Basic household wiring, automobile wiring, flashlights, tree lights, power lines; electrical conductivity testing.</p> |
| <p>5. Describe possible electrical hazards to be avoided at home and at school. (K-2)</p> <p><i>Key concepts:</i> Shock, wall outlet, hazards; see PME-IV.1 e.3 (electrical energy).</p> <p><i>Real-world contexts:</i> Electric outlets, power lines, frayed electric cords, electric appliances, lightning, hair dryers in sinks and tubs.</p> | <p>6. Investigate electrical devices and explain how they work, using instructions and appropriate safety precautions.</p> <p><i>Key concepts:</i> Flow of electricity for energy or information transfer. Safety precautions for using electrical appliances; grounding. Documentation for toys and appliances—wiring diagrams, written instructions. (See PCM-IV.2 m.3, transformations of energy.)</p> <p><i>Real-world contexts:</i> Situations requiring assembly, use, or repair of electrical toys, radios, or simple appliances, such as replacing batteries and bulbs; connecting electrical appliances, such as stereo systems, TV's and videocassette recorders, computers and computer components.</p> | <p>5. Describe how electric currents can be produced by interacting wires and magnets, and explain applications of this principle.</p> <p><i>Key concepts:</i> Current flow and direction, magnetic fields. See PMO-IV.3 m.4 (magnetism from electricity).</p> <p><i>Real-world contexts:</i> Generators, alternating current, direct current.</p> |

Changes in Matter (PCM) IV.2

Elementary	Middle School	High School
All students will investigate, describe and analyze ways in which matter changes:		
<p>1. Describe common physical changes in matter—size, shape; melting, freezing (K-2); dissolving, evaporating (3-5).</p> <p><i>Key concepts:</i> States of matter—solid, liquid, gas. Changes in size and shape—bending, tearing, breaking. Processes that cause changes of state: heating, cooling. See EH-V.2 e.1 (water in three states).</p> <p><i>Real-world contexts:</i> Changes in size or shape of familiar objects, such as making snowballs, breaking glass, crumbling cookies, making clay models, carving wood, breaking bones; changes in state of water or other substances, such as freezing of ice cream, or ponds, melting wax or steel, puddles drying up.</p>	<p>1. Describe common physical changes in matter: evaporation, condensation, sublimation, thermal expansion and contraction.</p> <p><i>Key concepts:</i> States of matter—solid, liquid, gas. Processes that cause changes of state or thermal effects: heating, cooling. Boiling. Mass/weight remains constant during physical changes in closed systems.</p> <p><i>Real-world contexts:</i> States of matter—solid, liquid, gas. Changes in state, such as water evaporating as clothes dry, condensation on cold window panes, disappearance of snow or dry ice without melting; expansion of bridges in hot weather, expansion and contraction of balloons with heating and cooling; solid air fresheners.</p>	(High school benchmarks related to changes in matter are in the next strand.)
<p>2. Prepare mixtures and separate them into their component parts.</p> <p><i>Key concepts:</i> Mixture, solution. Separation techniques—(K-2) filtration, using sieves, using magnets, floating vs. sinking; (3-5) dissolving soluble substances, evaporating.</p> <p><i>Tools:</i> Filter paper, funnels, magnets, sieves, beakers, solar stills.</p> <p><i>Real-world contexts:</i> Mixtures of various kinds—salt and pepper, iron filings and sand, sand and sugar, rocks and wood chips, sand and gravel, sugar or salt solutions.</p>	<p>2. Describe common chemical changes in terms of properties of reactants and products.</p> <p><i>Key concepts:</i> Common chemical changes—burning, rusting iron, formation of sugars during photosynthesis, acid reacting with metal and other substances. Mass/weight remains constant in closed systems.</p> <p><i>Real-world contexts:</i> Chemical changes—burning, photosynthesis, digestion, corrosion, acid reactions, common household chemical reactions such as with alkaline drain cleaners.</p>	

All students will explain how visible changes in matter are related to atoms and molecules:

(There are no elementary benchmarks about atoms or molecules.)

3. Explain physical changes in terms of the arrangement and motion of atoms and molecules.

Key concepts: Molecular descriptions of states of matter—see PME-IV.1 m.4. Changes in state of matter—melting, freezing, evaporation, condensation; thermal expansion and contraction (see PCM-IV.2 m.1). Speed of molecular motion—moving faster, slower, vibrate, rotate, unrestricted motion; change in speed of molecular motion with change in temperature.

Real-world contexts: See examples of physical changes of matter, PCM-IV.2 e.1 and m.1.

1. Explain chemical changes in terms of the breaking of bonds and the rearrangement of atoms to form new substances.

Key concepts: atom, molecule, ion, bond, reactant, product; conservation of mass; rate of reaction—temperature, surface area, concentration; specific chemical reactions—burning paper or wood, rusting iron, formation of sugars during photosynthesis. See PME-IV.1 h.3 (structure of the atom).

Real-world contexts: Examples of chemical changes—See PCM-IV.2 m.2.

2. Explain why mass is conserved in physical and chemical changes.

Key concepts: atom, molecule, mass.

Real-world contexts: Common physical and chemical changes, including matter cycles in ecosystems.

3. Contrast nuclear fission, nuclear fusion, and natural radioactivity.

Key concepts: Nucleus, nuclear change, force that hold nucleus together, nuclear energy. Stable and unstable isotopes. Properties—mass, element, radioactivity. See PME-IV.1 h.3 (structure of the atom).

Real-world contexts: Nuclear power plants, nuclear energy from sun, natural radioactive decay, use of radiation and radioactive isotopes in medicine.

All students will explain how changes in matter are related to changes in energy and how living things and human technology change matter and transform energy.

(For a related elementary benchmark, see PCM-IV.2 e.1, heating and cooling cause melting and freezing.)

4. Describe common energy transformations in everyday situations.

Key concepts: Forms of energy, including mechanical, heat, sound, light, electrical, magnetic, chemical, food energy. See PME-IV.1 m.5 (electricity in circuits), PCM-IV.2 m.1 (energy in changes of state). Total amount of energy remains constant in all transformations.

Real-world contexts: Motors, generators, power plants, light bulbs, appliances, cars, radios, TV's, walking, playing a musical instrument, cooking food, batteries, body heat, photosynthesis (see LO-III.2 m.3, LEC-III.5 m.2).

4. Describe energy transformations involved in physical, chemical and nuclear changes, and contrast their relative magnitudes.

Key concepts: Potential energy, kinetic energy, heat, light, electrical energy, chemical energy, sound; temperature changes. Original sources of energy: sun, radioactivity. Conservation of energy, conservation of mass/energy; $E=mc^2$. See PCM-IV.2 m.4 (common energy transformations), PCM-IV.2 h.3 (nuclear changes).

Real-world contexts: Common physical, chemical and nuclear changes, including changes of state, burning, electrical decomposition of water, photosynthesis, cellular respiration, fireworks and dynamite, nuclear power, stars.

5. Explain changes in matter and energy involving heat transfer.

Key concepts: Mechanisms of heat transfer — convection, conduction, radiation. Conservation of energy, efficiency. Changes in matter related to heat transfer—changes in temperature, volume, pressure. See PCM-IV.2 m.1 (thermal expansion), EAW-V.3 h.3 (convection).

Real-world contexts: Convection currents, lake turnover, wind, hot frying pans, heating and cooling buildings, heat lamps, sunlight heating the earth, greenhouse effect, fires for warming.

Motion of Objects (PMO) IV.3

Elementary	Middle School	High School
All students will describe how things around us move, explain why things move as they do, and demonstrate and explain how we control the motions of objects:		
<p>1. Describe or compare motions of common objects in terms of speed and direction.</p> <p><i>Key concepts:</i> Words—east, west, north, south, right, left, up, down. Speed words—fast, slow, faster, slower.</p> <p><i>Real-world contexts:</i> Motions of familiar objects in two dimensions, including rolling or thrown balls, wheeled vehicles, sliding objects.</p>	<p>1. Qualitatively describe and compare motion in two dimensions.</p> <p><i>Key concepts:</i> Two-dimensional motion—up, down, curved path. Speed, direction, change in speed, change in direction.</p> <p><i>Real-world contexts:</i> Objects in motion, such as thrown balls, roller coasters, cars on hills, airplanes.</p>	
<p>2. Explain how forces (pushes or pulls) are needed to speed up, slow down, stop, or change the direction of a moving object.</p> <p><i>Key concepts:</i> Changes in motion—speeding up, slowing down, turning. Common forces—push, pull, friction, gravity. Size of change is related to strength of push or pull.</p> <p><i>Real-world contexts:</i> Playing ball, moving chairs, sliding objects.</p>	<p>2. Relate motion of objects to unbalanced forces in two dimensions.</p> <p><i>Key concepts:</i> Changes in motion and common forces—speeding up, slowing down, turning, push, pull, friction, gravity, magnets. Constant motion and balanced forces. Additional forces—attraction, repulsion, action/reaction pair (interaction force), buoyant force. Size of change is related to strength of unbalanced force and mass of object.</p> <p><i>Real-world contexts:</i> Changing the direction—changing the direction of a billiard ball, bus turning a corner; changing the speed—car speeding up, a rolling ball slowing down, magnets changing the motion of objects, walking, swimming, jumping, rocket motion, objects resting on a table, tug-of-war.</p>	

3. Describe patterns of interaction of magnetic materials with other magnetic and non-magnetic materials.

Key concepts: Magnetic poles, magnetic attraction and repulsion.

Tools: Magnets, variety of magnetic and non-magnetic materials (K-2), magnetic compass (3-5).

Real-world contexts: Common magnets, using a magnetic compass to find direction.

3. Describe the non-contact forces exerted by magnets, electrically charged objects, and gravity.

Key concepts: Electrical charges and magnetic poles—north pole, south pole, positive charge, negative charge; mass, weight, gravitational pull. Charging by rubbing or touching, electric attraction and repulsion. Force depends on size of charges or masses, and decreases quickly with distance. See PMO-IV.3 m.2 (forces and motion), PME-IV.1 m.2 (weight and mass).

Real-world contexts: Electrically charged or polarized objects, such as balloons rubbed on clothing, bits of paper, salt grains, static cling, magnets, magnetic materials, earth's gravitational pull on objects near its surface, sun's gravitation pull on solar system objects (see ES-V.4 m.2).

4. Use electric currents to create magnetic fields, and explain applications of this principle.

Key concepts: Electric current, magnetic poles, magnetic fields. (See PME-IV.1 m.5, electric circuits.)

Tools: Magnetic compass, battery, wire.

Real-world contexts: Electromagnets, bells, speakers, motors, magnetic switches, Earth's magnetic field.

(A related benchmark about creating electrical currents from magnets is PME-IV.1 h.5.)

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| <p>4. Identify and use simple machines and describe how they change effort.</p> <p><i>Key concepts:</i> Inclined planes, levers, pulleys, wedges, wheel and axle; force, distance.</p> <p><i>Real-world contexts:</i> Block and tackles, ramps, screwdrivers and screws, can openers, see-saws.</p> | <p>5. Design strategies for moving objects by application of forces, including the use of simple machines.</p> <p><i>Key concepts:</i> Types of simple machines—lever, pulley, screw, inclined plane, wedge, wheel and axle, gear; direction change, force advantage, speed and distance advantage.</p> <p><i>Real-world contexts:</i> Objects being moved by using simple machines, such as wagons on inclined planes, heavy objects moved by levers, seesaw, cutting with knives or axes.</p> | <p>1. Analyze patterns of force and motion in the operation of complex machines.</p> <p><i>Key concepts:</i> Electrical and/or mechanical components of complex machines.</p> <p><i>Real-world contexts:</i> Machines, such as bicycles, automobiles, pumps, electrical motors.</p> |
| <p>5. Manipulate simple mechanical devices and explain how their parts work together.</p> <p><i>Key concepts:</i> Names and uses for parts of machines, such as levers, wheel and axles, pulleys, inclined planes, gears, screws, wedges.</p> <p><i>Real-world contexts:</i> Simple mechanical devices, such as bicycles, bicycle pumps, pulleys, faucets, clothespins, can openers.</p> | | |

All students will relate motion to energy and energy conversions:

(No corresponding benchmark at this level.)

(No corresponding benchmark at this level.)

2. Explain energy conversions in moving objects and machines.

Key concepts: Types of energy—electrical energy, kinetic energy, gravitational potential energy, potential energy in springs, chemical potential energy, heat energy, radiation. Energy transformations—see PCM-IV.2 m.4. Efficiency. See PME-IV.1 h.4 (conservation of energy) and PCM-IV.2 h.4 (energy in physical and chemical changes).

Real-world contexts: Simple and complex machines, roller coasters, swings, pendulums, elevators, automobiles, fans, motors.

Waves and Vibrations (PWV) IV.4

Elementary	Middle School	High School
All students will describe sounds and sound waves:		
<p>1. Describe sounds in terms of their properties.</p> <p><i>Key concepts:</i> Properties: pitch—high, low. Loudness—loud, soft.</p> <p><i>Real-world contexts:</i> Sound from common sources, such as musical instruments, radio, television, animal sounds, thunder, human voices.</p>	<p>1. Explain how sound travels through different media.</p> <p><i>Key concepts:</i> Media—solids, liquids, gases. Vacuum.</p> <p><i>Real-world contexts:</i> Sounds traveling through solids, such as glass windows, strings, the earth; sound traveling through liquids, such as dolphin and whale communication; sound traveling through gases, such as human hearing, sonic booms.</p>	<p>1. Relate characteristics of sounds that we hear to properties of sound waves.</p> <p><i>Key concepts:</i> Properties of sounds—pitch, volume. Characteristics of sound waves—frequency, amplitude, velocity.</p> <p><i>Real-world contexts:</i> Common sounds that vary in pitch and volume—see PWV-IV.4 e.1.</p>
<p>2. Explain how sounds are made.</p> <p><i>Key concepts:</i> Vibrations—fast, slow, large, small.</p> <p><i>Real-world contexts:</i> Sounds from common sources, such as musical instruments, radio, television, animal sounds, thunder, human voices.</p>	<p>2. Explain how echoes occur and how they are used.</p> <p><i>Key concepts:</i> Echo, sonar, reflection.</p> <p><i>Real-world contexts:</i> Echoes in rooms—acoustics—and outdoors; practical uses of echoes, such as navigation by bats and dolphins, ultrasound imaging, sonar.</p>	

All students will explain shadows, color, and other light phenomena:

3. Use prisms and filters with light sources to produce various colors of light.

Key Concepts: White light is composed of different colors.

Tools: Prisms, color filters, colored lights.

Real-world contexts: Light from common sources, such as sun, stars, light bulb, colored lights, firefly, candle, flashlight, various prisms.

4. Explain how shadows are made.

Key concepts: Shadow, blocked path, surface, object, light moves outward from source in straight lines.

Real-world contexts: Shadows made on surfaces by putting objects in the path of light from common sources, including sunlight, light bulbs, projectors. Changes in size of shadows due to distance from object.

3. Explain how light is required to see objects.

Key concepts: Light source, object, eye as a detector, illumination, path of light, reflection, absorption. See PWV-IV.4 m.2 (echo location).

Real-world contexts: Seeing common objects in our environment; seeing “through” transparent media, such as windows, water; using flashlights to see in the dark.

4. Describe ways in which light interacts with matter.

Key concepts: Reflection, refraction, absorption, transmission, scattering, medium, lens. Transmission of light—transparent, translucent, opaque.

Real-world contexts: Objects that reflect or absorb light, including mirrors; media that transmit light such as clear and frosted glass, clear and cloudy water, clear and smoky air; objects that refract light, including lenses, prisms, and fiber optics; uses of lenses, such as eye, cameras, telescope, microscope, magnifying lens, for magnification and light-gathering.

2. Explain how we see colors of objects.

Key concepts: Characteristics of light—brightness, amplitude, colors of spectrum (red, orange, yellow, green, blue, indigo, violet) wavelength, frequency (see PWV-IV.4 h.3). Ways that objects interact with light—emission, reflection, absorption, transmission, scattering (see PWV-IV.4 m.4).

Real-world contexts: Colored light-reflecting objects, such as books, clothes, color photographs; colored light-transmitting objects, such as stained glass, cellophane; colored light-emitting objects, such as television, neon lights. Scattering of light by the atmosphere.

All students will measure and describe vibrations and waves:

5. Describe the motion of vibrating objects.

Key concepts: Period, frequency, amplitude.

Real-world contexts: Vibrating or oscillating objects, such as weights on springs, vocal cords, tuning forks, guitar strings.

3. Describe waves in terms of their properties.

Key concepts: Mechanical waves, electromagnetic waves—see PWV-IV.4 h.4. Colors of light. Properties of waves—frequency, amplitude, wavelength, wave velocity, energy. Units of measurement—hertz or cycles per second, micrometers, meters, meters per second.

Tools for making spectra: Prism, diffraction grating.

Real-world contexts: Examples of mechanical and electromagnetic waves—see PWV-IV.4 h.4. Colors of light, frequencies of radio and TV transmission.

4. Describe different types of waves and their technological applications.

Key concepts: Types of waves—mechanical: sound, ultrasound, water waves, shock wave; electromagnetic: radio waves, microwaves, radiant heat, infrared radiation, visible light, ultraviolet radiation, x-rays. Properties of waves—see PWV-IV.4 h.3. See PCM-IV.2 m.4 (energy transformations).

Real-world contexts: Examples of mechanical waves—sound, ultrasound, ocean waves, wave tanks, earthquakes, seismic waves; examples of electromagnetic waves, such as light—see above, radio and television signals, heat lamps, microwave transmitters, radar, ultraviolet radiation in sunlight, X-ray machines, CAT-scans, gamma rays from radioactive decay.

All students will explain how waves and vibrations transfer energy:

(No elementary benchmark for this strand.)

6. Explain how mechanical waves transfer energy.

(No high school benchmark for this strand.)

Key concepts: Sound energy, absorption, transmission, reflection; media—air, solids, water.
(See PME-IV.1 m.6, electrical circuits transfer electrical energy.)

Real-world contexts: Waves in slinkies and long springs, sound waves, water waves, earthquakes.

Geosphere (EG) V.1

Elementary	Middle School	High School
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All students will describe the earth's surface:

1. Describe major features of the earth's surface.

Key concepts: Types of landforms—mountains, plains, valleys; bodies of water—rivers, oceans, lakes (see EH-V.2 e.2); deserts.

Real-world contexts: Examples of Michigan surface features, such as hills, valleys, rivers, waterfalls, Great Lakes; pictures of global land features, including mountains, deserts.

2. Recognize and describe different types of earth materials.

Key concepts: Materials—mineral, rock, boulder, gravel, sand, clay, soil.

Tools: Hand lens.

Real-world contexts: Samples of natural earth materials, such as rocks, sand, soil, ores.

1. Describe and identify surface features using maps.

Key concepts: Landforms—plains, deserts, plateaus, basin, Great Lakes, rivers, continental divide, mountains, mountain range, or mountain chain.

Tools: Maps—relief, topographic, elevation.

Real-world contexts: Maps showing continental and regional surface features, such as the Great Lakes or local topography.

(No high school benchmark for this strand.)

All students will describe and explain how the earth's features change over time:

3. Describe natural changes in the earth's surface.

Key concepts: Causes of changes—volcanoes, earthquakes, erosion (water, wind, gravity, glaciers). Results of change—valleys, hills, lakes, widened rivers, mountains, cracks, movement of earth materials (boulders, gravel, sand, clay).

Real-world contexts: Places around the school where erosion has occurred, such as gullies formed in down-hill gravel areas, cracks in asphalt. Places beyond the school where changes have occurred, such as volcanic mountains, shorelines, landslides, sand dunes, slopes, river valleys.

2. Explain how rocks are formed.

Key concepts: Rock cycle processes—melting and cooling (igneous rocks); heat and pressure (metamorphic rocks); cementing and crystallization of sediments (sedimentary rocks). Minerals. Heat source is interior of earth. Materials—silt, clay, gravel, sand, rock, lava, magma, remains of living things (bones, shells, plants).

Real-world contexts: Physical environments where rocks are being formed: volcanoes; depositional environments, such as ocean floor, deltas, beaches, swamps; metamorphic environments deep within the earth's crust.

3. Explain how rocks are broken down, how soil is formed and how surface features change.

Key concepts: Chemical and mechanical weathering; erosion by glaciers, water, wind and downslope movement; decomposition, humus.

Real-world contexts: Regions in Michigan where erosion by wind, water, or glaciers may have occurred, such as river valleys, gullies, shoreline of Great Lakes; chemical weathering from acid rain, formation of caves, caverns and sink holes; physical weathering, frost action such as potholes and cracks in sidewalks; plant roots by bacteria, fungi, worms, rodents, other animals.

1. Explain the surface features of the Great Lakes region using Ice Age theory.

Key concepts: Glacial processes—climate change, snow changing to ice, pressure, moving (advance, retreat), melting; deposits; features—hills, lakes, Great Lakes. See EAW-V.3 h.1 (long-term climate change.)

Tools: Relief map, topographic map, elevation map.

Real-world contexts: Examples in Michigan of glacial formations, such as moraines, kettles, drumlins.

2. Use the plate tectonics theory to explain features of the earth's surface and geological phenomena and describe evidence for the plate tectonics theory.

Key concepts: Earth composition—crust, mantle: upper part is able to flow very slowly; core: interior at high temperature and pressure (see ES-V.4 h.3.) Forces—tension, compression shearing. Plates—continental crust, oceanic crust. Features—faults, trenches, mid-ocean ridges, folded mountains, hot spots, volcanoes. Related actions—earthquakes (see PWV-IV.4 m.6), volcanic activity, seafloor spreading, mountain building, convection in mantle. Evidence of “continental drift”—physical fit of continents, fossil evidence, measurements of movement, rock layer sequences, glacial evidence. See Reflecting on Scientific Knowledge benchmarks related to evidence and theory.

Real-world contexts: Recent patterns of earthquake and volcanic activities; maps showing the direction of movement of major plates and associated earthquake and volcanic activity; compressional boundaries: folded mountains, thrust faults, trenches, lines of volcanoes (e.g. Pacific “ring of fire”); tensional boundaries: mid-ocean ridges, rift valleys; shearing boundaries: lateral movement producing faults (e.g. San Andreas Fault).

4. Explain how rocks and fossils are used to understand the history of the earth.
4. Explain how rocks and fossils are used to understand the age and geological history of the earth.

Key concepts: Fossils, extinct plants and animals, ages of fossils, rock layers. See LE-III.4 e.1 (ancient life.)

Real-world contexts: Fossils found in gravel, mines, quarries, beaches (Petosky stones), museum displays; Michigan examples of layered rocks; specific examples of extinct plants and animals, such as dinosaurs.

Key concepts: Fossils, extinct plants and animals, ages of fossils, rock layers, timelines, relative dating.

Real-world contexts: Fossils found in gravel, mines and quarries, museum displays; places where rock layers are visible, such as Pictured Rocks, quarries, Grand Canyon, road cuts; Michigan fossils, such as trilobites, brachiopods, Petosky stones; specific examples of extinct plants and animals, such as dinosaurs.

All students will analyze effects of technology on the earth's surface and resources:

5. Describe uses of materials taken from the earth.

Key concepts: Transportation, building materials, energy, water (see EH-V.2 e.3.)

Real-world contexts: Examples of uses of earth materials, such as gravel into concrete for walls, gypsum into drywall, sand into glass for windows, road salt, ores into metal for chairs, oil into gasoline for cars, coal burned to produce electricity, water for hydroelectric power. Samples of manufactured materials, such as concrete, drywall, asphalt, iron and steel.

6. Demonstrate ways to conserve natural resources and reduce pollution through reduction, reuse, and recycling of manufactured materials.

Key concepts: Materials that can be recycled—paper, metal, glass, plastic. Conservation and anti-pollution activities—reduce, reuse, recycle.

Real-world contexts: Collections of recyclable materials, plans for recycling at home and school, composting, ways of reusing or reducing the use of paper.

5. Explain how technology changes the surface of the earth.

Key concepts: Types of human activities—surface mining, construction and urban development, farming, dams, landfills, restoring natural areas.

Real-world contexts: Local example of surface changes due to human activities listed in the Key concepts above; local examples of negative consequences of these changes, such as groundwater pollution, destruction of habitat and scenic land, reduction of arable land; local examples of positive consequences, such as soil conservation, reforestation, restoring wetlands.

3. Explain how common objects are made from earth materials and why earth materials are conserved and recycled.

Key concepts: Valuable materials—minerals, metallic ores, iron, copper, aluminum, fuels. Types of resources—renewable, nonrenewable. Conservation, limits, recycling, costs for developing more remote supplies. Manufacturing, refining, mining. Recycling processes—melting, shredding, dissolving.

Real-world contexts: Manufacturing processes—steel mills, auto assembly lines, paper making; local recycling center for materials, such as glass, plastic, aluminum, steel cans, motor oil; examples of technical and social means for slowing the depletion of earth's resources, such as developing more fuel-efficient cars and mandating their use; disposal in landfills and incinerators.

4. Evaluate alternative long range plans for resource use and by-product disposal in terms of environmental and economic impact.

Key concepts: Understanding of limitations of knowledge and technology (see R-II.1 h.2), side effects of resource use (see PME-IV.1 h.1, risk/benefit analysis). Also see R-II.1 h.5 (new technologies), EAW-V.3 h.4 (air pollution),

Real-world contexts: Industries for mining, energy production, manufacturing, transportation, housing. Resources including fossil fuels, metals, wood, water. Pollution prevention and events, such as catalytic converters, Love Canal, Superfund waste sites.

Hydrosphere (EH) V.2

Elementary	Middle School	High School
All students will describe the characteristics of water and demonstrate where water is found on earth:		
<p>1. Describe how water exists on earth in three states.</p> <p><i>Key concepts:</i> Liquid (K-2)—visible, flowing, melting, dew. Solid (K-2)—hard, visible, freezing, ice. Gas (3-5)—invisible, water vapor, moisture, evaporating. See PCM-IV.2 e.1.</p> <p><i>Real-world contexts:</i> Examples of water in each state, including dew, rain, snow, ice, evidence of moisture in the air, such as “fog” on cold bathroom mirrors; examples of melting, freezing, and evaporating.</p>	<p>1. Use maps of the earth to locate water in its various forms and describe conditions under which they exist.</p> <p><i>Key concepts:</i> Liquid water forms—lakes, rivers, oceans, springs. Frozen water forms—continental glacier, valley glacier, snow on mountains, polar cap. Gaseous water in atmosphere.</p> <p>Tools: Relief and elevation maps; satellite images</p> <p><i>Real-world contexts:</i> Local lakes, rivers, streams, ponds, springs; examples of frozen water, including snow, glaciers, icebergs, polar regions, frozen Great Lakes shorelines.</p>	(No high school benchmark for this strand.)

All students will describe how water moves:

<p>2. Trace the path that rain water follows after it falls.</p> <p><i>Key concepts:</i> Precipitation—see EAW-V.3 e.1. Flow—downhill, to rivers, into the ground. Bodies of water—streams, rivers, lakes, oceans. See EG-V.1 e.1 (earth features).</p> <p><i>Real-world contexts:</i> Examples of water flowing locally, including gutters, drains, streams, wetlands.</p>	<p>2. Describe how surface water in Michigan reaches the ocean and returns.</p> <p><i>Key concepts:</i> Water path—run-off, creeks, streams, wetlands, rivers, Great Lakes. Sources—snow melt, rain fall. Gravity. Water cycle—see EAW-V.3 m.3. (See EH-V.2 m.3 about groundwater.)</p> <p><i>Real-world contexts:</i> Maps showing streams, lakes, rivers, oceans; examples of motions of rivers and lakes; investigations of rivers and lake temperatures; saltiness of ocean.</p>	<p>1. Identify and describe regional watersheds.</p> <p><i>Key concepts:</i> drainage basins, divides, reservoirs, tributaries, run-off.</p> <p><i>Tools:</i> maps</p> <p><i>Real-world contexts:</i> Local and regional watersheds, Great Lakes Basin, Continental Divide; planning water management, evaluating potential disposal sites, analyzing pollution events which concern both surface and ground water.</p>
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All students will analyze the interaction of human activities with the hydrosphere:

3. Identify sources of water and its uses.

Key concepts: Water sources—wells, springs, Great Lakes, rivers. Household uses—drinking, cleaning, food preparation. Public uses—generate electricity, recreation, irrigation, transportation, industry.

Real-world contexts: Examples of local sources of drinking water, including wells, rivers, lakes. Examples of local occasions when water is used, including car wash, swimming, fire hydrants, drinking, food preparation, cleaning, watering lawn, bathing, fishing, boating, shipping on the Great Lakes.

3. Explain how water exists below the earth's surface and how it is replenished.

Key concepts: Ground water—water table, spring, porous, saturate, filtration. Sources—snow melt, rain fall.

Real-world contexts: Examples of groundwater, including springs, wells, water soaking into the ground.

4. Describe the origins of pollution in the hydrosphere.

Key concepts: Sources of pollution—sewage, household dumping, industrial wastes, agricultural run-off. See EG-V.1 m.5, LEC-III.5 m.6.

Real-world contexts: Examples of polluted water; examples of occasions when water supply is restricted, such as during droughts.

2. Describe how human activities affect the quality of water in the hydrosphere.

Key concepts: Human activities—agriculture, fishing, manufacturing, energy production. Quantity of water—rate of use, urbanization. Oceans—oil spills, garbage, global warming, marine life. Fresh water pollution—industrial waste disposal, agricultural run-off, herbicides, pesticides, sewage, acid rain, nutrient levels. Ground water—landfills, leaching, disposal of toxic wastes. Purification technology—filtering, chlorination. Limits to natural resources.

Real-world contexts: Examples of local and regional human activities that have measurable effects on water, including farming, industry, sewage disposal, toxic waste disposal.

Atmosphere and Weather (EAW) V.3

Elementary	Middle School	High School
All students will investigate and describe what makes up weather and how it changes from day to day, from season to season and over long periods of time:		
<p>1. Describe weather conditions.</p> <p><i>Key concepts:</i> Atmosphere is a blanket of air around the earth, air is a substance; see PME-IV.1 e.1 (attributes of substances). Air has temperature—cold, hot, warm, cool. Cloud cover—cloudy, partly cloudy; foggy. Precipitation—rain, snow, hail, freezing rain. Wind—breezy, windy, calm. Severe weather—thunderstorms, lightning, tornadoes, high winds, blizzards.</p> <p><i>Tools:</i> Thermometer, wind sock, rain gauge.</p> <p><i>Real-world contexts:</i> Daily changes in weather; examples of severe weather.</p>	<p>1. Explain patterns of changing weather and how they are measured.</p> <p><i>Key concepts:</i> Weather patterns—cold front, warm front, stationary front, air mass, humidity.</p> <p><i>Tools:</i> Thermometer, rain gauge, wind direction indicator, anemometer, weather maps, satellite weather images.</p> <p><i>Real-world contexts:</i> Sudden temperature and cloud formation changes; records, charts, and graphs of weather changes over periods of days; lake effect snow.</p>	<p>1. Explain how interactions of the atmosphere, hydrosphere and geosphere create climates and how climates change over time.</p> <p><i>Key concepts:</i> Average yearly temperatures; ice ages, volcanic dust in atmosphere, greenhouse effect, global air circulation, effects of latitude, effects of landforms, ocean currents.</p> <p><i>Real-world contexts:</i> Causes of short-term climate changes, such as catastrophic volcanic eruptions and impact of solar system objects; evidence of long-term climate changes, such as ice ages, global warming. El Nino, La Nina.</p>
<p>2. Describe seasonal changes in Michigan's weather.</p> <p><i>Key concepts:</i> Seasons and types of weather—fall, cool nights and warm days; winter—snowy and constantly cold, getting dark early in the evening; spring—warmer days, often rainy with thunderstorms; summer—hot days and warm nights, daylight lasting until late in the evening.</p> <p><i>Real-world contexts:</i> Examples of visible seasonal changes in nature.</p>		

All students will explain what causes different kinds of weather:

(No elementary benchmark for this strand.)

2. Describe the composition and characteristics of the atmosphere.

Key concepts: Composition—air, molecules, gas, water vapor, dust particles, ozone. Characteristics—air pressure and temperature changes with altitude, humidity.

Real-world contexts: Examples of characteristics of the atmosphere, including pressurized cabins in airplanes, demonstrations of air pressure; examples of air-borne particulates, such as smoke, dust, pollen, bacteria; effects of humidity, such as condensation, dew on surfaces, comfort level of humans.

3. Explain the behavior of water in the atmosphere.

Key concepts: Water cycle—evaporation, water vapor, warm air rises, cooling, condensation, clouds. Precipitation—rain, snow, hail, sleet, freezing rain. Relative humidity, dew point, fog. See PCM-IV.2 m.1 (changes of state), EH-V.2 m.2 (water on the earth's surface).

Real-world contexts: Aspects of the water cycle in weather, including clouds, fog, precipitation, evaporating puddles, flooding, droughts.

2. Describe patterns of air movement in the atmosphere and how they affect weather conditions.

Key concepts: Air movement—air masses, fronts, pressure systems, prevailing winds, jet stream.

Real-world contexts: Reports of local weather patterns influenced by the jet stream and prevailing winds.

3. Explain and predict general weather patterns and storms.

Key concepts: Weather patterns—cold front, warm front, stationary front, air mass, high and low pressure systems. Storms—thunderstorms, lightning and thunder, tornadoes, hurricanes, winds, blizzards. Buoyancy, thermal expansion, convection. See PCM-IV.2 m.1 (thermal expansion) and PME-IV.1 m.1 (density).

Tools: Weather maps, thermometer, hygrometer, barometer, anemometer, wind vane, rain gauge, satellite and radar monitoring (see PWV-IV.4 h.4).

Real-world contexts: Observable daily weather patterns; examples of weather reports from TV, radio, newspapers, including representations on weather maps. Reports of local weather patterns influenced by the jet stream and prevailing winds.

All students will analyze the relationships between human activities and the atmosphere:

3. Explain appropriate safety precautions during severe weather.

Key concepts: Safety precautions—safe locations, sirens, radio broadcasts, severe weather watch and warning.

Real-world contexts: Examples of local severe weather, including thunderstorms, tornadoes and blizzards, examples of local community safety precautions, including weather bulletins and tornado sirens.

4. Describe health effects of polluted air.

Key concepts: Effects—breathing difficulties, irritated eyes. Sources—car exhaust, industrial emissions. Acid rain.

Real-world contexts: Locations and times where air quality is poor; local sources of potential air pollution; ozone warnings.

4. Explain the impact of human activities on the atmosphere and explain ways that individuals and society can reduce pollution.

Key concepts: Air pollution—car exhaust, industrial emissions, smog. Related effects—breathing problems, acid rain, global warming, deforestation, ozone depletion. See EG-V.1 h.4 (resource use).

Real-world contexts: Examples of human activities that affect the atmosphere, including use of aerosol spray cans, discharge from smoke stacks, car exhaust, burning leaves and wood in stoves and fireplaces, climate change, global warming; actions, including turning off lights, turning down heat, tuning-up cars, filling tires, driving at a consistent speed, mandating higher fuel efficiencies, energy savings from recycling.

Solar System, Galaxy and Universe (ES) V.4

Elementary	Middle School	High School
All students will compare and contrast our planet and sun to other planets and star systems.		
<p>1. Compare and contrast characteristics of the sun, moon and earth.</p> <p><i>Key concepts:</i> Planet, star, sphere, space, solar system, larger/smaller, closer/farther, heat, light.</p> <p><i>Real-world contexts:</i> Observations of the moon, earth, and safe observations of the sun.</p>	<p>1. Compare the earth to other planets and moons in terms of supporting life.</p> <p><i>Key concepts:</i> Surface conditions—gravity, atmospheres, temperature. Relative distances, relative sizes. Sun produces the light and heat for each planet. Molecules necessary to support life—water, oxygen, nitrogen, carbon; see LC-III.1 m.2 (cell processes), LO-III.2 m.3 (photosynthesis), LEC-III.5 m.2 (light needed for energy).</p> <p><i>Real-world contexts:</i> Examples of local and extreme conditions on earth vs. conditions on other planets; exploration of planets and their satellites.</p>	<p>1. Compare our sun to other stars.</p> <p><i>Key concepts:</i> Temperatures, colors, sizes, apparent and absolute brightness; double stars.</p> <p><i>Real-world contexts:</i> Observing color and brightness of stars, observing double stars.</p>

All students will describe and explain how objects in the solar system move.

2. Describe the motion of the earth around the sun and the moon around the earth.

Key concepts: Spin, orbit, length of day, nighttime, month, year, observed movement of the sun and stars across the sky, observed movement of the moon from day to day, calendar.

Real-world contexts: Outdoor observing of the sun's and star's motions during the night and moon's motions over several days.

2. Describe, compare, and explain the motions of solar system objects.

Key concepts: Orbit, rotation (spin), axis, gravity, planets, moons, comets, asteroids, seasons. Tilt of the earth on its axis, direct/indirect rays. See PMO-IV.3 m.2 (force and change in motion) and PMO-IV.3 m.3 (gravity).

Real-world contexts: Observations of comet motion over days and weeks, length of day and year on planets, changes in length of daylight and height of sun in sky; changes in daily temperature patterns; summer and winter solstices, spring and fall equinoxes.

3. Describe and explain common observations of the night skies.

Key concepts: Perceived and actual movement of the moon and planets across the sky, moon phases, eclipses, stars and constellations, planets, Milky Way, comets, comet tails, meteors. Sun is light source for all solar system objects (except meteors; friction with atmosphere), emitted light, reflected light (see PWV-IV.4 m.3 and m.4.)

Real-world contexts: Outdoor observing of the skies, using telescopes and binoculars when available, as well as "naked-eye" viewing; viewing with robotic telescopes via the World Wide Web; telescopic and spacecraft-based photos of planets, moons, and comets; news reports of planetary and lunar exploration.

2. Describe the position and motion of our solar system in our galaxy and the overall scale, structure and age of the universe.

Key concepts: Stars, galaxies, Milky Way, spiral structure, speed of light, light year, travel times, big bang, red shift.

Tools: Telescopes, binoculars, *spectroscopes*

Real-world contexts: Observations of other stars, star clusters, nebulae, and galaxies, observations of other potential planetary systems, accounts of possible travel to other star systems.

All students will explain scientific theories as to the origin of the solar system

(No elementary benchmark for this strand.)

(No middle school benchmark for this strand.)

3. Explain how stars and planetary systems form and how stars produce energy.

Key concepts: Processes of formation—coalescence from clouds of dust and gases by gravity; explosions of stars producing heavy elements; hydrogen, helium. Production of energy—fusion, radiation. Planetary systems may form during this process—heavy and light elements, hot interiors of earth-like planets. Age of the solar system.

Real-world contexts: Nebulas considered to be star-forming regions, supernovas, nuclear fusion research.

All students will explain how we learn about the universe.

(No elementary benchmark for this strand.)

(No middle school benchmark for this strand.)

4. Explain how technology and scientific inquiry have helped us learn about the universe.

Key concepts: Information—radiant energy, radio waves, light, spectra, color of stars, moon and meteor samples. Devices—radio, optical and other types of telescopes, space probes, satellites, computer imaging/modeling (see PWV-IV.4 h.4.) Problems for investigation—geology and weather of planets and moons, origins, extraterrestrial life.

Real-world contexts: Histories of discoveries, stories of exploration, visits to observatories and planetariums; videos showing space exploration; samples of space materials, including moon rocks and meteorites; remote sensing data; SETI—Search for Extraterrestrial Life.