ADOPTED JULY 2011

Ohio's New Learning Standards:

Science Standards

Ohio | Department of Education

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Ohio Revised Science Education Standards and Model Curriculum

OVERVIEW

This overview reiterates the vision and goals of the *Ohio Revised Science Education Standards and Model Curriculum,* provides the guiding principles that framed the development of the materials, and contains the definitions used in the documents. It also contains draft definitions for the *Cognitive Demands* that have guided the development of the *Expectations for Learning* component.

VISION

The *Ohio Revised Academic Content Standards and Model Curriculum for Science Education* serve as a basis for what all students should know and be able to do in order to become scientifically literate citizens equipped with knowledge and skills for the 21st century workforce and higher education. Ohio educators are provided with the content and expectations for learning upon which to base science curriculum at each grade level. By the end of high school, students should graduate with sufficient proficiency in science to:

- Know, use and interpret scientific explanations of the natural world;
- Generate and evaluate scientific evidence and explanations, distinguishing science from pseudoscience;
- Understand the nature and development of scientific knowledge;
- Participate productively in scientific practices and discourse.[1]

The PreK-8 and high school documents are designed to provide guidance for educators who have the responsibility to teach science to Ohio students. Each *Content Statement and Content Elaboration* presents what students should know about that science. The accompanying *Expectations for Learning* incorporate science skills and processes, and technological and engineering design. The *Visions into Practice* section offers optional examples of tasks that students may perform to learn about the science as well as demonstrate their mastery of the grade-level materials. The *Instructional Strategies and Resources* section further subdivides into sections on *Diverse Learners, Common Misconceptions and Classroom Portals*.

It is the blending of the *Content Statements and Content Elaborations* with the *Expectations for Learning* that will provide the basis for future assessments.

GOALS

Ohio's student-centered goals (Duschl et. al., 2007; Bell et. al. 2009) for science education include helping students:

1. Experience excitement, interest and motivation to learn about phenomena in the natural and physical world.
2. Come to generate, understand, remember and use concepts, explanations, arguments, models and facts related to science.
3. Manipulate, test, explore, predict, question, observe and make sense of the natural and physical world.
4. Reflect on science as a way of knowing; on processes, concepts and institutions of science; and on their own process of learning about phenomena.
5. Participate in scientific activities and learning practices with others, using scientific language and tools.
6. Think about themselves as science learners and develop an identity as someone who knows about, uses and sometimes contributes to science.

These goals are consistent with the expectations noted in Am. Sub. House Bill 1.[2]

[1] Paraphrased from Bruce Alberts, past President of the National Academy of Science and current editor of *Science Magazine*. Retrieved from the web on April 13, 2010: http://www.whitehouse.gov/files/documents/ostp/PCAST/Alberts.pdf.

[2] ORC §3301.079 A (1): http://codes.ohio.gov/orc/3301.

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GUIDING PRINCIPLES

The Revised Science Education Standards have been informed by international and national studies, educational stakeholders and academic content experts. The guiding principles include:

- **Definition of Science:** Science is a systematic method of continuing investigation, based on observation, scientific hypothesis testing, measurement, experimentation and theory building, which leads to explanations of natural phenomena, processes or objects that are open to further testing and revision based on evidence.[3] Scientific knowledge is logical, predictive and testable, and grows and advances as new evidence is discovered.
- **Scientific Inquiry:** There is no science without inquiry. Scientific inquiry is a way of knowing and a process of doing science. It is the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work. Scientific inquiry also refers to the activities through which students develop knowledge and understanding of scientific ideas as well as an understanding of how scientists study the natural world.[4] Teachers need to model scientific inquiry by teaching with inquiry.
- **21st Century Skills:** 21st century skills are integral to the science standards and curriculum development revision documents. They are an essential part of the model curriculum component through the incorporation and integration of scientific inquiry, science skills and process and technological and engineering design. As enumerated by Am. Sub. H.B. 1, these skills include: creativity and innovation; critical thinking, problem solving and communication; information, media and technological literacy; personal management, productivity, accountability, leadership and responsibility; and interdisciplinary, project-based, real-world learning opportunities.[5]
- **Technological Design:** Technological design is a problem or project-based way of applying creativity, science, engineering and mathematics to meet a human need or want. Modern science is an integrated endeavor. Technological design integrates learning by using science, technology, engineering and mathematics and fosters 21st Century Skills.
- **Technology and Engineering:** Technology modifies the natural world through innovative processes, systems, structures and devices to extend human abilities. Engineering is design under constraint that develops and applies technology to satisfy human needs and wants. Technology and engineering, coupled with the knowledge and methods derived from science and mathematics, profoundly influence the quality of life.
- **Depth of Content:** It is vital that the *Content Statements and Content Elaborations* within the standards document communicate the most essential concepts and the complexity of the discipline in a manner that is manageable and accessible for teachers. The focus is on what students must know to master the specific grade-level content. The *Expectations for Learning* cognitive demands provide the means by which students can demonstrate this grade-level mastery.
- **Internationally Benchmarked:** Ohio's Revised Science Education Standards and Model Curriculum incorporate research from investigations of the science standards of:
  - Countries whose students demonstrate high-performance on both the Trends in International Mathematics and Science Studies (TIMSS) and Program in Student Assessment (PISA) tests; and
  - States with students who perform well on the National Assessment of Education Progress (NAEP).

  As a result, there is a clear focus on rigor, relevance, coherence and organization, with an emphasis on horizontal and vertical articulation of content within and across disciplines.
- **Assessment:** Ohio's assessment system will be informed by and aligned with the *Content Statements, Content Elaborations and Expectations for Learning*.
- **Standards and Curriculum:** The Standards and Model Curriculum provide a framework from which local curricula can be developed. They themselves are not the curriculum. The curriculum will continue to be a local responsibility.

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[3] National Research Council (1996), *National Science Education Standards* (Washington, DC: National Academy Press) and including excerpts with minor revision, of The Ohio Academy of Science (2000) definition of science: http://www.ohiosci.org/Whatisscience. PDF Acc

[4] Research Council (1996), *National Science Education Standards* (Washington, DC: National Academy Press), p 192.

[5] http://www.21stcenturyskills.org/index.php?option=com_content&task=view&id=254&Itemid=119; ORC §3301.079 A (1): http://codes.ohio.gov/orc/3301.

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FORMAT AND DEVELOPMENT OF THE STANDARDS AND MODEL CURRICULUM

The Standards and Model Curriculum are a Web-based resource that provides information and support on "How" to plan, develop, implement and evaluate instruction directly aligned to standards. They include *Content Elaborations; Expectations for Learning* that will incorporate additional information on teaching strategies through the *Examples for the Classroom; Visions into Practice,* and *Instructional Strategies*, with selected resources and suggestions for *Diverse Learners, Common Misconceptions* and *Classroom Portals*. Every PreK to 8 Content Statement is accompanied by a Model Curriculum. Each high school course also is accompanied by a Model Curriculum aligned to specific topical areas. Table 1 contains the definitions for each of the terms used.

The *Content Elaborations, Expectations for Learning* and accompanying *Visions into Practice* examples were developed by ODE staff in collaboration with education stakeholders. The definitions of the four *Cognitive Demands* of the *Expectations for Learning* that guided the development of the *Visions into Practice* were compiled from research and national frameworks. Table 2 provides descriptions for each of the four *Cognitive Demands*.

The *Instructional Strategies and Resources* sections were populated with recommendations from ODE staff and recommendations from the field. During the summer of 2010, 144 meetings were held throughout the 16 State Support Team Regions. These meetings provided opportunities for teachers to contribute to the *Instructional Strategies* components. In addition, more than 60 professional and industrial organizations in science or science-related technological and engineering fields were contacted for recommendations on real-world applications relevant to the revised science education standards. Members of the Ohio Academy of Sciences and members of higher education faculty also were invited to participate.

The *Instructional Strategies and Resources* portion of the Model Curriculum is intended to be dynamic. When fully functional as a Web-based interactive system, it will be able to be updated regularly to reflect current research and to ensure that links to suggested teaching resources and materials remain active.

TRANSITION PERIOD

The Revised Science Education Standards and Model Curriculum will not be fully implemented until 2014 to allow time for development of aligned assessments. However, even though the new materials look different to accommodate more specificity and have a different emphasis by eliminating indicators and focusing on depth of content, scientific inquiry has been at the core of all the development.

Teachers can begin to transition to the new materials by becoming familiar with the new format and the *Expectations for Learning* framed by the *Cognitive Demands* and by continuing to implement the Scientific Inquiry/Learning Cycle that has been recommended by ODE since 2002. All components of the Model Curriculum are compatible with the 5Es of the Learning Cycle.

The process of scientific inquiry incorporates universal skills, such as collaboration, critical thinking, problem solving, communication, research and meta-cognition that are commonly thought of as 21st century process skills. Teaching by inquiry allows students to learn and demonstrate both scientific skills and technological/engineering design skills which addresses the goals of career and college readiness.

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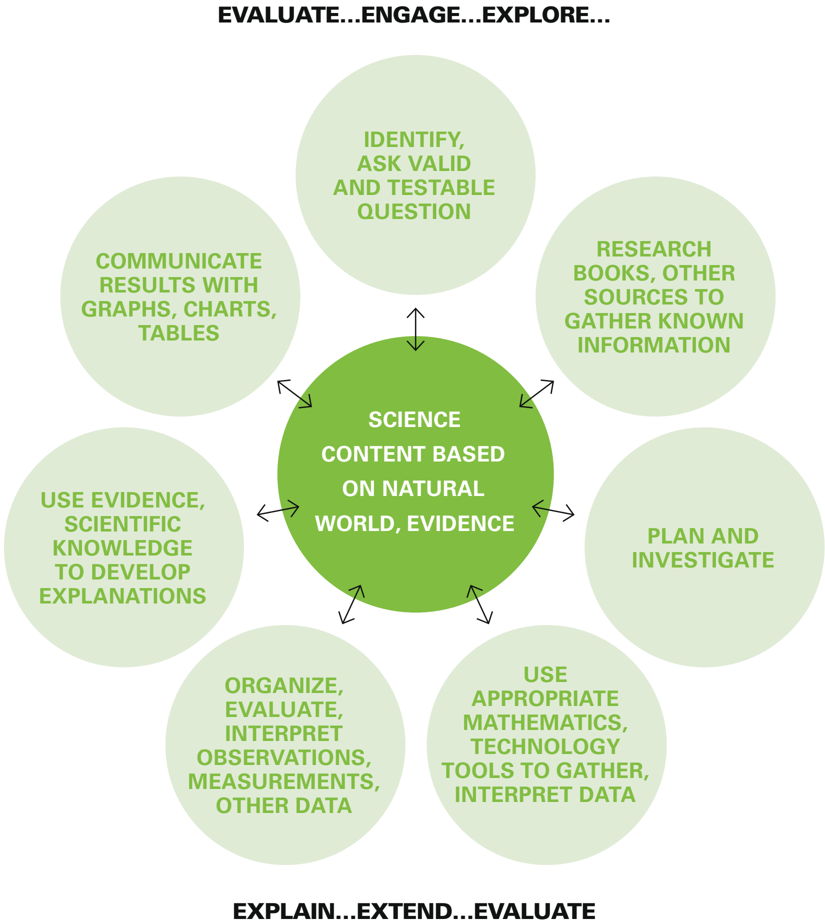
SCIENTIFIC INQUIRY/LEARNING CYCLE



Teachers using the 5Es and grounded in the content of the revised science standards will be able to:

- Scaffold their students in framing questions, grappling with data, creating explanations, and critiquing explanations (including others in public forum) – all important components of inquiry.
- Select instructional materials from the Model Curriculum that promote the teaching and learning of science by inquiry.
- Assess students' abilities in multiple ways that are compatible with inquiry.

Students engaging with grade appropriate science content in depth through the Scientific Inquiry/Learning Cycle will be better prepared to meet the challenges they will be confronting as they enter higher education or pursue a career.

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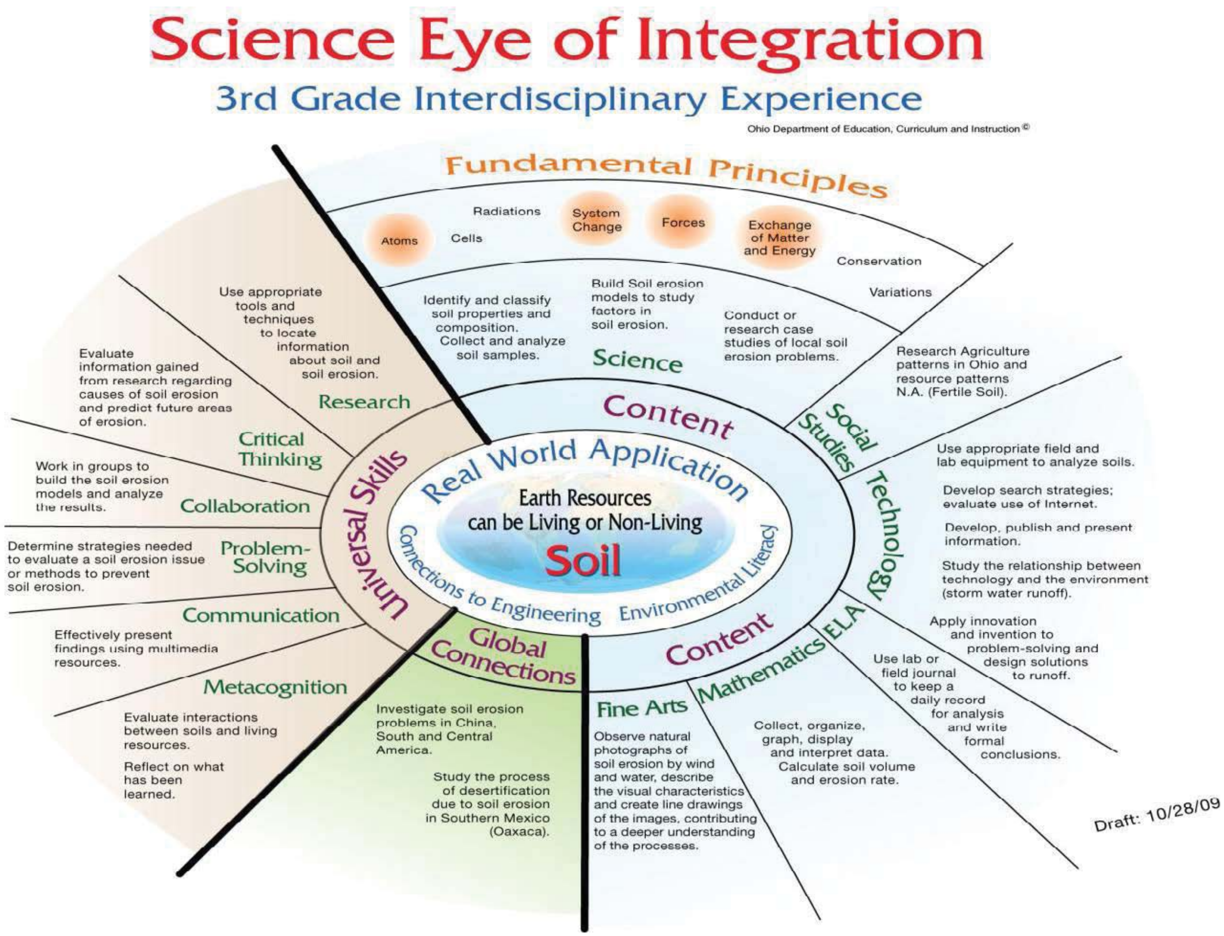
VISION FOR THE FUTURE

The *Eye of Integration* is a vision for the future. It is a Web-based portal to be developed following Phase II, the Model Curriculum.



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Model Curriculum Definitions

Strands: These are the science disciplines: Earth and space sciences, physical sciences; life science. Overlaying all the content standards and embedded in each discipline are science inquiry and applications.

Grade Band Themes: These are the overarching ideas that connect the strands and the topics within the grades. Themes illustrate a progression of increasing complexity from grade to grade that is applicable to all the strands.

Strand Connections: These are the overarching ideas that connect the strands and topics within a grade. Connections help illustrate the integration of the content statements from the different strands.

Topics: The Topics are the main focus for content for each strand at that particular grade level. The Topics are the foundation for the specific content statements.

Content Statements: These state the science content to be learned. These are the "what" of science that should be accessible to students at each grade level to prepare them to learn about and use scientific knowledge, principles and processes with increasing complexity in subsequent grades.

Note: The content statements and associated model curriculum may be taught in any order. The sequence provided here does not represent the ODE-recommended sequence as there is no ODE-recommended sequence.

Model Curriculum: The Model Curriculum is a Web-based resource that will incorporate information on "how" the material in the Content Statement may be taught. It will include Content Elaboration, Learning Expectations, and Instructional Strategies and Resources (described below).

Content Elaboration: This section provides anticipated grade-level depth of content knowledge and examples of science process skills that should be integrated with the content. This section also provides information to help identify what prior knowledge students should have and toward what future knowledge the content will build.

Expectations for Learning: This section provides definitions for Ohio's science cognitive demands, which are intrinsically related to current understandings and research about how people learn. They provide a structure for teachers and assessment developers to reflect on plans for teaching science, to monitor observable evidence of student learning, and to develop summative assessment of student learning of science. Ohio's cognitive demands for science include designing technological and engineering solutions using scientific concepts, demonstrating scientific knowledge, interpreting and communicating scientific concepts and recalling accurate science.

Vision into Practice: This section provides optional examples of tasks that students may perform, these task are not mandated. It includes designing technological and engineering solutions using scientific concepts, demonstrating scientific knowledge, interpreting and communicating scientific concepts and recalling accurate science. This provides guidance for developing classroom performance tasks and assessments. These are examples not an all-inclusive checklist of what should be done, but a springboard for generating innovative ideas.

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Instructional Strategies and Resources: This section provides additional support and information for educators. These are strategies for actively engaging students with the topic and for providing hands- on-minds-on observation and exploration of the topic, including authentic data resources for scientific inquiry, experimentation and problem-based tasks that incorporate technology, and technological and engineering design. Resources selected are printed or Web-based materials that directly relate to the particular Content Statement. This section is not intended to be a prescriptive list of lessons.

Subcategories of Instructional Strategies and Resources include:

- **Common Misconceptions:** This section identifies misconceptions that students often have about the particular Content Statement. When available, links to resources are provided that describe the misconception and that offer suggestions for helping students overcome them.
- **Diverse Learners:** This section will include ideas about different ways of approaching a topic to take into consideration diverse learning styles. It will contain a variety of instructional methods designed to engage all students to help them gain deep understanding of content through scientific inquiry, technology and technological and engineering design.
- **Classroom Portals:** This section provides windows into the classroom through webcasts, podcasts and video clips to exemplify and model classroom methods of teaching science using inquiry and technological design.

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Resources: Frameworks that were consulted in the development of the draft cognitive demands are listed below. Each links to a brief description of the framework.

NAEP: *Science Framework for the 2009 National Assessment of Educational Progress* (2008), http://www.nagb.org/publications/frameworks/science-09.pdf.

Revised Bloom's Taxonomy: See Anderson, et.al. *A Taxonomy for Learning, Teaching and Assessing* (2001), http://projects.coe.uga.edu/epltt/index.php?title=Bloom%27s_Taxonomy.

TIMSS: *TIMSS 2007 Assessment Frameworks* (2005), http://timss.bc.edu/TIMSS2007/PDF/T07_AF_chapter2.pdf.

Survey of Enacted Curriculum: *Coding Procedures for Curriculum Content Analyses* (2004), http://seconline.wceruw.org/Reference/K12Taxonomy08.pdf.

PISA: *The PISA 2003 Assessment Domains* (2003), http://www.oecd.org/dataoecd/46/14/33694881.pdf.

Ohio's Technology Standards: Ohio Academic Content Standards in Technology (2003), http://www.ode.state.oh.us/GD/Templates/Pages/ODE/ODEPrimary.aspx?Page=2&TopicID=1696&TopicRelationID=1707.

Table 1: Ohio's Cognitive Demands for Science

OHIO REVISED SCIENCE STANDARDS MODEL CURRICULUM: EXPECTATIONS FOR LEARNING COGNITIVE DEMANDS

As with all other frameworks and cognitive demand systems, Ohio's revised system has overlap between the categories. *Recalling Accurate Science* is a part of the other three cognitive demands included in Ohio's framework, because science knowledge is required for students to demonstrate scientific literacy.

COGNITIVE DEMAND	DESCRIPTION
DESIGNING TECHNOLOGICAL/ ENGINEERING SOLUTIONS USING SCIENCE CONCEPTS (T)	Requires student to solve science-based engineering or technological problems through application of scientific inquiry. Within given scientific constraints, propose or critique solutions, analyze and interpret technological and engineering problems, use science principles to anticipate effects of technological or engineering design, find solutions using science and engineering or technology, consider consequences and alternatives, and/or integrate and synthesize scientific information.
DEMONSTRATING SCIENCE KNOWLEDGE (D)	Requires student to use **scientific inquiry** and develop the ability to think and act in ways associated with inquiry, including asking questions, planning and conducting investigations, using appropriate tools and techniques to gather and organize data, thinking critically and logically about relationships between evidence and explanations, constructing and analyzing alternative explanations, and communicating scientific arguments. (Slightly altered from National Science Education Standards) **Note: Procedural knowledge (knowing how) is included in *Recalling Accurate Science*.**
INTERPRETING AND COMMUNICATING SCIENCE CONCEPTS (C)	Requires student to use subject-specific conceptual knowledge to interpret and explain events, phenomena, concepts and experiences using grade-appropriate scientific terminology, technological knowledge and mathematical knowledge. Communicate with clarity, focus and organization using rich, investigative scenarios, real-world data and valid scientific information.
RECALLING ACCURATE SCIENCE (R)	Requires students to provide accurate statements about scientifically valid facts, concepts and relationships. Recall only requires students to provide a rote response, declarative knowledge or perform routine mathematical tasks. This cognitive demand refers to students' knowledge of science fact, information, concepts, tools, procedures (being able to describe how) and basic principles.

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Table 2: Expectations for Technological and Engineering Design

OHIO REVISED SCIENCE STANDARDS MODEL CURRICULUM

Below are examples of the grade-appropriate skills expected of students as they become engaged in the cognitive domain of *Designing Technological/ Engineering Solutions Using Science Concepts.*[1] These skills complement those of scientific inquiry that are expected to be achieved by the end of the selected grade bands in PreK-8 and at the end of high school.

TECHNOLOGICAL AND ENGINEERING DESIGN	
PREK-4	**GRADES 5-8**
Identify problems and potential technological/engineering solutions	Understand and be able to select and use physical and informational technologies
Understand the design process, role of troubleshooting	Understand how all technologies have changed over time
Understand goals of physical, informational and bio-related technologies	Recognize role of design and testing in the design process
Understand how physical technologies impact humans	Apply research, innovation and invention to problem solving

TECHNOLOGICAL AND ENGINEERING DESIGN GRADES 9-12
Demonstrate an understanding of the relationship among people, technology, engineering and the environment
Identify a problem or need, consider design criteria and constraints
Integrate multiple disciplines when problem solving
Synthesize technological and engineering knowledge and design in problem solving
Apply research, development, experimentation and redesign based on feedback to problem solving
Build, test and evaluate a model or prototype that solves a problem or a need

[1] *Ohio Academic Content Standards for Technology*, December 2003 (Ohio Department of Education). *Technology for All Americans: A Rationale and Structure for All Americans Project*, 1996 (International Technology Association, Reston, VA).

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Description of a Scientific Model

A scientific model is a mental construct that represents a large-scale system or process. The model may be abstract, conceptual, mathematical, graphical and/or computer-based. Scientific models are valuable to promote understanding of interactions within and between systems and to explain and predict observed phenomena as simply as possible. It is important to note that scientific models are incomplete representations of the actual systems and phenomena. They can change over time as new evidence is discovered that cannot be explained using the old model. Since the goal of a model is to promote understanding, simpler, less complete models can still be used when more advanced and complex models do little to contribute to the understanding of the phenomenon considered. For example, the quantum model of the atom would not necessarily be the best model to use to understand the behavior of gases.

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Ohio Revised Science Standards and Model Curriculum Grades PreK through Eight

INDEX:

TOPICS BY GRADE LEVEL

KINDERGARTEN
Earth, Life, Physical

GRADE 1
Earth, Life, Physical

GRADE 2
Earth, Life, Physical

GRADE 3
Earth, Life, Physical

GRADE 4
Earth, Life, Physical

GRADE 5
Earth, Life, Physical

GRADE 6
Earth, Life, Physical

GRADE 7
Earth, Life, Physical

GRADE 8
Earth, Life, Physical

LEGEND

ENVIRONMENTAL LITERACY

TECHNOLOGY LITERACY

21ST CENTURY SKILLS

EYE OF INTEGRATION EXAMPLE

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Topics by Grade Level

THEMES		THE PHYSICAL SETTING: EARTH AND SPACE SCIENCE	THE PHYSICAL SETTING: PHYSICAL SCIENCE	THE LIVING ENVIRONMENT: LIFE SCIENCE
Observations of the Environment This theme focuses on helping students develop the skills for systematic discovery to understand the science of the natural world around them in greater depth by using scientific inquiry.	K	*Living and nonliving things have specific physical properties that can be used to sort and classify. The physical properties of air and water are presented as they apply to weather.*		
		Daily and Seasonal Changes	Properties of Everyday Objects and Materials	Physical and Behavioral Traits of Living Things
	1	*Energy is observed through movement, heating, cooling and the needs of living organisms.*		
		Sun, Energy and Weather	Motion and Materials	Basic Needs of Living Things
	2	*Living and nonliving things may move. A moving object has energy. Air moving is wind and wind can make a windmill turn. Changes in energy and movement can cause change to organisms and the environment in which they live.*		
		The Atmosphere	Changes in Motion	Interactions within Habitats
Interconnections within Systems This theme focuses on helping students explore the components of various systems and then investigate dynamic and sustainable relationships within systems using scientific inquiry.	3	*Matter is what makes up all substances on Earth. Matter has specific properties and exists in different states Earth's resources are made of matter, can be used by living things and can be used for the energy they contain. There are many different forms of energy. Each living component of an ecosystem is composed of matter and uses energy.*		
		Earth's Resources	Matter and Forms of Energy	Behavior, Growth and Changes
	4	*Heat and electrical energy are forms of energy that can be transferred from one location to another. Matter has properties that allow the transfer of heat and electrical energy. Heating and cooling affect the weathering of Earth's surface and Earth's past environments. The processes that shape Earth's surface and the fossil evidence found can help decode Earth's history.*		
		Earth's Surface	Electricity, Heat and Matter	Earth's Living History
	5	*Cycles on Earth, such as those occurring in ecosystems, in the solar system and in the movement of light and sound, result in describable patterns. Speed is a measurement of movement. Change in speed is related to force and mass*. The transfer of energy drives changes in systems, including ecosystems and physical systems.*		
		Cycles and Patterns in the Solar System	Light, Sound and Motion	Interactions within Ecosystems
Order and Organization This theme focuses on helping students use scientific inquiry to discover patterns, trends, structures and relationships that may be inferred from simple principles. These principles are related to the properties or interactions within and between systems.	6	*All matter is made of small particles called atoms. The properties of matter are based on the order and organization of atoms and molecules. Cells, minerals, rocks and soil are all examples of matter.*		
		Rocks, Minerals and Soil	Matter and Motion	Cellular to Multicellular
	7	*Systems can exchange energy and/or matter when interactions occur within systems and between systems. Systems cycle matter and energy in observable and predictable patterns.*		
		Cycles and Patterns of Earth and the Moon	Conservation of Mass and Energy	Cycles of Matter and Flow of Energy
	8	*Systems can be described and understood by analysis of the interaction of their components. Energy, forces and motion combine to change the physical features of the Earth. The changes of the physical Earth and the species that have lived on Earth are found in the rock record. For species to continue, reproduction must be successful.*		
		Physical Earth	Forces and Motion	Species and Reproduction

SCIENCE INQUIRY AND APPLICATIONS

During the years of PreK to grade 4, all students must develop the ability to:

- Observe and ask questions about the natural environment;
- Plan and conduct simple investigations;
- Employ simple equipment and tools to gather data and extend the senses;
- Use appropriate mathematics with data to construct reasonable explanations;
- Communicate about observations, investigations and explanations; and
- Review and ask questions about the observations and explanations of others.

During the years of grades 5 through 8, all students must have developed the ability to:

- Identify questions that can be answered through scientific investigations;
- Design and conduct a scientific investigation;
- Use appropriate mathematics, tools and techniques to gather data and information;
- Analyze and interpret data;
- Develop descriptions, models, explanations and predictions;
- Think critically and logically to connect evidence and explanations;
- Recognize and analyze alternative explanations and predictions; and
- Communicate scientific procedures and explanations.

*While mass is the scientifically correct term to use in this context, the **NAEP 2009 Science Framework** (page 27) recommends using the more familiar term "weight" in the elementary grades with the distinction between mass and weight being introduced at the middle school level. In Ohio, students will not be assessed on the differences between mass and weight until Grade 6.

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