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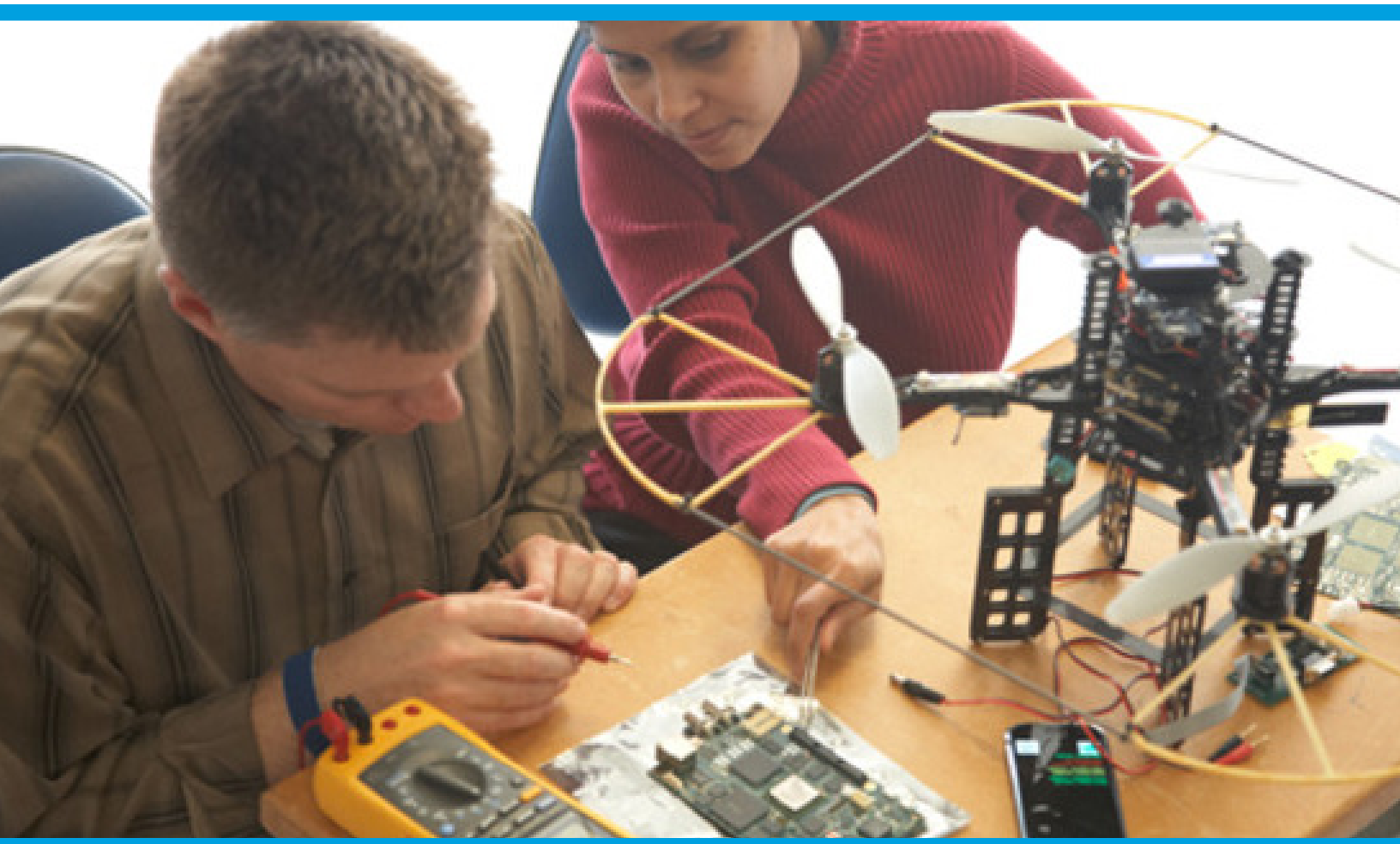

A Content Comparison Analysis of the

Next Generation Science Standards and the Michigan Science Standards

Center for Technology in Learning

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Executive Summary

The Michigan Department of Education (MDE) and Wayne Regional Education Service Agency contracted with SRI International's Center for Technology in Learning to conduct an external, independent content comparison review of the Michigan Science Standards (MSS) and the Next Generation Science Standards (NGSS).

The methodology used for this review involved an initial examination of the standards, using the three dimensions from the National Research Council's report: *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (NRC, 2012), which are the foundations of the NGSS; (Scientific and Engineering Practices, Crosscutting Concepts, and Disciplinary Core Ideas) and the MSS as outlined in the Science Grade Level Content Expectations for K-7 and the High School Science Essential Content Standards and Expectations. A crosswalk framework was created for each comparison review that defines the areas in each set of standards to be compared. A scale was developed that provides a rating for the degree of match between the content areas. Color coding was used to represent similar content. While the color chosen has no particular significance, the amount of color indicates the degree of similarity (see Appendix I and Appendix II).

An analysis of the similarities, partial matches, and differences between content in the NGSS and the MSS Science Grade Level Content Expectations for K-7 and the High School Science Essential Content Standards and Expectations was conducted. Findings indicate a Low to Moderate Match between the NGSS and the MSS Science Grade Level Content Expectations for K-7, and the NGSS comparison with the MSS High School Science Essential Content Standards and Expectations.

Examples of unique features of the NGSS that were not found in the MSS include: a) the NGSS science concepts build coherently from grade to grade, while implementing crosscutting concepts that are integrated within core content; b) the NGSS provide progressions across grade bands for the Earth and Space Sciences, Life Sciences and Physical Sciences; c) the NGSS are aligned with the Common Core State Standards in English Language Arts and Mathematics; and d) the NGSS provide performance expectations in new content areas such as Engineering, which is defined and integrated with Science and Technology in the NGSS from K–12.

These results provide compelling evidence of the value added by the adoption of the NGSS to improve science education in Michigan. Recommendations from these findings include:

- Michigan should consider the adoption of the NGSS performance expectations, in order to improve science education for students in all grades.

- The NGSS Science and Engineering Practices and Crosscutting Concepts provide coherence across content areas and should be implemented to enhance current science education instruction for grades K-12.

- The NGSS performance expectations for the Disciplinary Core Ideas in Engineering, Technology and Application of Science contain new content that should be included in science instruction across all grades.

- The NGSS performance expectations provide explicit connections to Common Core Mathematics and English Language Arts Standards that should be integrated into science instruction.

- NGSS Professional Development Resources are available through participation in the NGSS Network and should be leveraged to support Michigan science teachers.

- NGSS resources for formative and summative assessment development should be utilized by Michigan science teachers to support classroom instruction.

A rationale that supports each recommendation is provided, along with examples of resources for professional development, curriculum transitions and assessment development.

A Content Comparison Analysis of the

Next Generation Science Standards and the Michigan Science Standards

Introduction

The Michigan Department of Education (MDE) and Wayne Regional Education Service Agency contracted with SRI International's Center for Technology in Learning to conduct an external, independent content comparison review of the Michigan Science Standards (MSS) and the Next Generation Science Standards (NGSS). By using the three dimensions from the National Research Council's report: *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (NRC, 2012), which are the foundations of the NGSS; (Scientific and Engineering Practices, Crosscutting Concepts, and Disciplinary Core Ideas), and the MSS as outlined in the Science Grade Level Content Expectations for K-7 and the High School Science Essential Content Standards and Expectations , this review compared the NGSS with the MSS. An analysis was conducted in order to identify similarities, partial matches, and differences between content in the NGSS and the MSS. An overall rating of the degree of match was determined for each standards comparison. and each of the two sets of MSS standards was determined.

Implications of the findings from this review are addressed through the following research questions: 1) 'To what extent would the adoption of the NGSS represent an improvement over current Michigan Science Standards, based on *the Framework for K-12 Science Education* (NRC, 2012)?', 2) 'What are the opportunities for implementation support?', and 3) 'What are some suggestions for how any weaknesses inherent in an NGSS adoption could be compensated for in implementation planning?' A table is provided that describes recommendations for Michigan, along with a rationale that supports each recommendation.

Overview of the Standards

The purposes of the NGSS and MSS are similar but distinct. The following description provides background information regarding the formulation and focus of each of these sets of standards, and describes an overview of the content addressed.

Michigan Science Standards

The Michigan Science Grade Level Content Expectations and the Michigan High School Science Essential Content Standards and Expectations I were developed by Michigan's Scholar Work Group in response to the No Child Left Behind Act, 2001. Resources used in the development of these documents included the 2009 National Assessment of Educational Progress Framework, the National Science Education Standards (1996), the Michigan Curriculum Framework in Science (2000), and the Atlas for Science Literacy, (2001 and 2007). In addition, resources such as Taking Science to School: Learning and Teaching Science in Grades K-8 (2007) were utilized (Science v.1.09 Grade Level Content Expectations, Michigan Department of Education).

The purpose of the Science Grade Level Content Expectations for K-7 is to provide clarity for what students are expected to know and be able to do by the end of each grade, (Science v.1.09 Grade Level Content Expectations, Michigan Department of Education). The Science Grade Level Content Expectations for K-7 focus on four Disciplines: Science Processes, Physical Science, Life Science, and Earth Science. The Science Processes include; Inquiry Process, Inquiry Analysis and Communication, and Reflection and Social Implications. The performance expectations for Physical Science, Life Science, and Earth Science outline the essential learning expected of students at each grade level.

The purpose of the Michigan High School Science Essential Content Standards and Expectations is to establish what every student is expected to know and be able to do by the end of high school. They include the Key Practices of Science Literacy, and the four Disciplines of Earth Science, Biology, Physics, and Chemistry. The Key Practices of Science Literacy include; Identifying Science Principles, Using Science Principles, Scientific Inquiry, and Reflection and Social Implications, (High School Science Essential Content Standards and Expectations, v.11/06). Since the Key Practices of Identifying Science Principles and Using Science Principles are considered to be prerequisite science content that all students should bring to high school science classes, the Essential Content Standards for High School only address Scientific Inquiry and Reflection and Social Implications.

Next Generation Science Standards

The Next Generation Science Standards ("NGSS") were developed by twenty-six states, in collaboration with partners (see http://www.nextgenscience.org/development-overview) (the "Lead States and Partners") in a process managed by Achieve, Inc. ("Achieve"). Michigan teachers participated in the development and review of these standards.

In 2012, the National Research Council (NRC) of the National Academy of Sciences authored *A Framework for K-12 Science Education: Practices, Crosscutting Concepts and Core Ideas.* This document provides the underlying basis for the Next Generation Science Standards, which draw on evidence-based research in science, including research on the ways students learn science effectively (NGSS). As part of the NGSS development process, the NRC convened a fidelity review of the final draft of the NGSS that compared the standards to the vision outlined in the *Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (NRC, 2012). The reviewers concluded that the NGSS are consistent with the content and structure of the framework document.

The NGSS are based on three dimensions from the *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (NRC, 2012). These dimensions provide the foundation for the NGSS performance expectations, which clarify what students will know and be able to do by the end of each grade or grade band. According to the *Framework* (NRC, 2012), the Practices describe behaviors that scientists engage in as they investigate and build models and theories about the natural world and the key set of engineering practices that engineers use as they design and build models and systems. The Crosscutting Concepts have application across all domains of science. The Disciplinary Core Ideas are designed to focus on what students should know by the time they graduate from high school (see NGSS Appendix A, page 4). They are based on progressions outlined in the *Framework* (NRC, 2012), and include the Physical Sciences, Life Sciences, Earth and Space Sciences, and Engineering, Technology, and Application of Science. Engineering and technology are also integrated into all grade levels in the NGSS, in order to promote students' understanding of science and to prepare them to solve the practical problems confronting modern society.

Methodology for Crosswalk Development

An initial examination of each set of standards was conducted. The NGSS were examined using the three dimensions from the NRC's report: *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (NRC, 2012), which are the foundations of the NGSS; (Scientific and Engineering Practices, Crosscutting Concepts, and Disciplinary Core Ideas). The MSS were examined using the Disciplines (Science Processes, Physical Science, Life Science, and Earth Science) for grades K-7 as outlined in the Science Grade Level Content Expectations and the Earth Science, Biology, Physics and Chemistry for High School from the High School Science Essential Content Standards and Expectations. A crosswalk framework was developed for each comparison review (see Tables 2 and 4), that defines the areas in each set of standards to be compared. A scale that describes the degree of match between each comparison (see Table 1) was used to rate each comparison category. An overall rating of the degree of match found among all categories was then calculated.

Table 1. Criteria for rating the degree of match between the NGSS and the MSS

Criteria for Match Between Comparison Categories on Standards	Degree of Match Between Standard Categories
No identified match	No Match
A few matches between concepts and terms	Low Match
Some matches between concepts and terms	Low to Moderate
Several matches between concepts and terms	Moderate Match
Most concepts and terms match	High Match

Content Comparison Analysis of

NGSS and the MSS Grade Level Content Expectations for K-7

Introduction for K-7 Comparison

The following describes the content comparison analysis results and the degree of match found between the NGSS and the MSS Grade Level Content Expectations for K-7. Similarities, partial matches, and differences are described for each comparison. The framework in Table 2 illustrates the design of the crosswalk for the Next Generation Science Standards and the Michigan Science Standards for grades K-7.

Table 2. Framework for comparison review of the NGSS and MSS Grade Level Content Expectations for Grades K-7

NGSS		MSS	
Scientific and Engineering Practices	⟷	**Science Processes**	
Asking questions and defining problems Developing and using models Planning and carrying out investigations Analyzing and interpreting data Using mathematics and computational thinking Constructing explanations and designing solutions Engaging in argument from evidence Obtaining, evaluating, and communicating information		Inquiry Process Inquiry Analysis and Communication Reflection, and Social Implications	
Crosscutting Concept	⟷	**Disciplines**	
Patterns Cause and effect Scale, proportion, and quantity Systems and system models Energy and matter Structure and function Stability and change		Physical Science Force and Motion Energy Properties of Matter Life Science: Organization of Living Things Heredity Evolution Ecosystems	Earth Science Earth Systems Solid Earth Fluid Earth Earth in Space and Time
Disciplinary Core Ideas	⟷	**Disciplines (all of the above)**	
Physical Sciences Life Sciences Earth and Space Sciences		Physical Science Life Science Earth Science	
Disciplinary Core Ideas	⟷	**Science Processes**	
Engineering, Technology and Application of Science		Inquiry Reflection, and Social Implications	

Results of the NGSS and MSS Grade Level Content Expectations for K-7 Crosswalk Analysis

This section describes the content comparison analysis results and the degree of match found between the NGSS and the MSS Grade Level Content Expectations for K-7. Similarities, partial matches, and differences are described for each comparison (see Appendix I for data tables).

NGSS Scientific and Engineering Practices and MSS Disciplines of Science Processes

NGSS Scientific and Engineering Practices

- Asking questions (for science) and defining problems (for engineering),
- Developing and using models,
- Planning and carrying out investigations,
- Analyzing and interpreting data,
- Using mathematics and computational thinking,
- Constructing explanations (for science) and designing solutions (for engineering)
- Engaging in argument from evidence,
- Obtaining, evaluating, and communicating information.

MSS Science Processes

- **Inquiry Process:** Develop an understanding that scientific inquiry and reasoning involves observing, questioning, investigating, recording, and developing solutions to problems.

- **Inquiry Analysis and Communication:** Develop an understanding that scientific inquiry and investigations require analysis and communication of findings, using appropriate technology. Inquiry includes an analysis and presentation of findings that lead to future questions, research, and investigations.

- **Reflection and Social Implications:** Develop an understanding that claims and evidence for their scientific merit should be analyzed. Understand how scientists decide what constitutes scientific knowledge. Develop an understanding of the importance of reflection on scientific knowledge and its application to new situations to better understand the role of science in society and technology.

Degree of Match: Low

The NGSS Scientific and Engineering Practices and the MSS Disciplines of Science Processes were found to have a low degree of match, based on content.

Similarities: Similarities in both sets of standards exist in regard to references to questioning, investigating, analyzing, using evidence, and communicating information.

Partial Match: A partial match was found with the NGSS Scientific and Engineering Practices and the MSS Science Processes in regard to investigations and analysis. While the NGSS mention planning and carrying out investigations and analyzing and interpreting data, the MSS focus on developing an understanding that investigations require analysis.

Differences: Only the NGSS included references to "Developing and using models," "Interpreting data," and "Using mathematics and computational thinking." References to "engineering." in regard to "designing solutions" were missing from the MSS, as were references to "engaging in argument," or "obtaining and evaluating information."

Only the MSS for K-7 included references to inquiry and reasoning. References to technology were included in the MSS, and are noted below in comparison to the NGSS Domain of Engineering, Technology, and Applications of Science.

NGSS Crosscutting Concepts and MSS Disciplines of Physical Science, Life Science, and Earth Science

NGSS Crosscutting Concepts

- Patterns
- Cause and effect
- Scale, proportion, and quantity
- Systems and system models
- Energy and matter
- Structure and function
- Stability and change

MSS Disciplines of Physical Science, Life Science, and Earth Science

- Physical Science
- Life Science
- Earth Science

Degree of Match: Low

The NGSS Crosscutting Concepts were found to have a Low degree of match across the MSS Disciplines of Physical Science, Life Science, and Earth Science. Though some similarities were found, many of the NGSS Crosscutting Concepts were only referenced in one or two of the MSS Disciplines.

- **NGSS Crosscutting Concepts of Patterns:** Observed patterns of forms and events guide organization and classification, and they prompt questions about relationships and the factors that influence them.
- **MSS Disciplines of:** Physical Science, Life Science, and Earth Science

Similarities: Similarities include references to patterns and relationships in both the NGSS and in the MSS Discipline of Earth in Space and Time.

Differences: Differences exist in the MSS in regard to patterns. The MSS only address patterns in Earth in Space and Time in regard to "Patterns of Objects in the Sky," while the NGSS Crosscutting Concepts refer to observed patterns of forms and events that guide organization and classification, and prompt questions about relationships and the factors that influence them.

- **NGSS Crosscutting Concepts of Cause and Effect:** Mechanism and explanation. Events have causes, sometimes simple, sometimes multifaceted. A major activity of science is investigating and explaining causal relationships and the mechanisms by which they are mediated. Such mechanisms can then be tested across given contexts and used to predict and explain events in new contexts.
- **MSS Disciplines of:** Physical Science, Life Science, and Earth Science

Similarities: Both the NGSS and MSS reference science and relationships.

Partial Match: A partial match exists regarding the NGSS crosscutting concepts of "causal relationships and mechanisms by which they are mediated" and the MSS reference to "relationships." However, rather than referencing relationships across disciplines, the MSS refer to "relationships among organisms" specifically in the discipline of Life Science: Evolution. The MSS only address effects in regard to Ecosystems in Life Sciences, rather than across all disciplines.

Differences: Only the NGSS include references to "Mechanisms that can be tested across given contexts and used to predict and explain events in new contexts."

- **NGSS Crosscutting Concepts of Scale, Proportion, and Quantity:** In considering phenomena, it is critical to recognize what is relevant at different measures of size, time, and energy and to recognize how changes in scale, proportion, or quantity affect a system's structure or performance.
- **MSS Disciplines of:** Physical Science, Life Science, and Earth Science

Similarities: Both the MSS and NGSS reference time, energy, changes, systems and structure.

Partial Match: A partial match was found in regard to systems. However, while the NGSS refer to a "system's structure and performance," the MSS reference "Animal Systems."

Differences: Only the NGSS mention measures of size and how quantity affects a system's structure or performance.

- **NGSS Crosscutting Concepts of Systems and System Models.** Defining the system under study—specifying its boundaries and making explicit a model of that system—provides tools for understanding and testing ideas that are applicable throughout science and engineering.
- **MSS Disciplines of:** Physical Science, Life Science, and Earth Science

Similarities: Both standards address systems and science.

Differences: Only the NGSS include references regarding "making explicit a model of a system" and "tools for understanding and testing ideas that are applicable throughout science and engineering."

- **NGSS Crosscutting Concepts of Energy and Matter:** Flows, cycles, and conservation. Tracking fluxes of energy and matter into, out of, and within systems helps one understand the systems' possibilities and limitations.
- **MSS Disciplines of:** Physical Science, Life Science, and Earth Science

Similarities: Both standards address the concepts of energy, matter, cycles, time and systems.

Partial Match: A partial match was found in regard to the NGSS references to "systems possibilities and limitations" and the MSS "Animal Systems."

Differences: Only the NGSS include references to "Flows, cycles and conservation," as well as "Tracking fluxes of energy and matter into, out of, and within systems."

- **NGSS Crosscutting Concepts of Structure and Function.** The way in which an object or living thing is shaped and its substructure determine many of its properties and functions.
- **MSS Disciplines of:** Physical Science, Life Science, and Earth Science

Similarities: The NGSS and MSS similarly address the concepts of "Structure and Function."

Differences: Only the NGSS include references to "substructure."

- **NGSS Crosscutting Concepts of Stability and Change:** For natural and built systems alike, conditions of stability and determinants of rates of change or evolution of a system are critical elements of study.
- **MSS Disciplines of:** Physical Science, Life Science, and Earth Science

Similarities: Both the NGSS and MSS reference change, systems, and evolution.

Partial Match: A partial match exists between the NGSS reference to "natural and built systems" and the MSS "Animal Systems."

Differences: Only the NGSS include references to "stability," as well as references to rates of change or evolution of a system.

NGSS Disciplinary Core Ideas and the MSS K-7 Disciplines of Physical Science, Life Science and Earth Science

NGSS Disciplinary Core Ideas

- Physical Sciences
- Life Sciences
- Earth and Space Sciences
- Engineering, Technology, and Applications of Science

MSS Grade Level Content Expectations for K-7 Disciplines

- Physical Science
- Life Science
- Earth Science

Degree of Match: Moderate

A Moderate match was found between the NGSS Disciplinary Core Ideas and the MSS Disciplines of Physical Science, Life Science and Earth Science.

- **NGSS Physical Sciences:** PS1: Matter and its interactions; PS2: Motion and stability: Forces and interactions; PS3: Energy; PS4: Waves and their applications in technologies for information transfer.
- **MSS Physical Science:** Forces in Motion, Energy, Properties of Matter, and Changes in Matter.

Similarities: Both the NGSS and MSS include references to matter, interactions, forces, energy, waves and transfer.

Partial Match: While waves and transfer are addressed in both sets of standards, only the NGSS include references to "Waves and their applications in technologies for information transfer."

Differences: Only the NGSS address stability. Only the MSS address references to chemical changes and chemical properties.

- **NGSS Life Sciences:** LS1: From molecules to organisms: Structures and processes; LS2: Ecosystems: Interactions, energy, and dynamics; LS3: Heredity: Inheritance and variation of traits; LS4: Biological evolution: Unity and diversity.
- **MSS Life Science:** Organization of Living Things, Heredity, Evolution, and Ecosystems.

Similarities: Both the NGSS and MSS address Organisms, Inheritance, Traits, Evolution, Ecosystems, and Interactions.

Partial Match: The NGSS reference Structures and Processes, while the MSS address Structures and Functions.

Differences: Only the NGSS include references to "molecules," "energy and dynamics," and "unity and diversity."

- **NGSS Earth and Space Sciences:** ESS1: Earth's place in the universe; ESS2: Earth's systems; ESS3: Earth and human activity.
- **MSS Earth and Space**: Earth Science, Solid Earth, Fluid Earth, and Earth in Space and Time.

Similarities: Both the NGSS and MSS address Earth and Space, Systems and the Earth.

Partial Match: The NGSS reference Human Activity, while the MSS address Human Impact and Human Consequences.

Differences: Only the NGSS include references to "Earth's place in the Universe."

NGSS Engineering, Technology, and Applications of Science

- ETS1: Engineering design,
- ETS2: Links among engineering, technology, science and society.

MSS Inquiry Analysis and Communication and Reflection and Social Implications

- Develop an understanding that claims and evidence for their scientific merit should be analyzed. Understand how scientists decide what constitutes scientific knowledge. Develop an understanding of the importance of reflection on scientific knowledge and its application to new situations to better understand the role of science in society and technology.

Degree of Match: Low

A Low to Moderate degree of match was found between the NGSS Engineering, Technology, and Applications of Science.

Similarities: Similarities include references to technology and science and society.

Partial Match: A partial match was found in reference to the NGSS concept of "Links among engineering, technology, science, and society" and the MSS concept of "the role of science in society and technology."

Differences: Only the NGSS include references to "engineering design," and links among "engineering, technology, science and society."

Summary

The overall degree of match between the MSS Grade Level Content Expectations for K-7 and the NGSS was determined to be "Low to Moderate" (Table 3, see Appendix I for results in each category).

Table 3. Results of the NGSS and the MSS Grade Level Content Expectations for K-7 Content Comparison Analysis

Next Generation Science Standards	Michigan Science Standards for K-7	Degree of Match
Scientific and Engineering Practices	Science Processes	Low Match
NGSS Crosscutting Concepts	MSS Disciplines	Low Match
NGSS Disciplinary Core Ideas	MSS Disciplines	Moderate Match
Overall Degree of Match		**Low to Moderate Match**

The NGSS Scientific and Engineering Practices and MSS Disciplines of Science Processes were fairly similar in how they address science; however, only the NGSS include references to engineering, developing and using models, and using mathematics and computational thinking. These differences indicated a Low degree of match.

The NGSS Crosscutting Concepts differed in the degree of representation within each of the MSS K-7 Disciplines of Physical Science, Life Science and Earth Science. Though both the NGSS and the MSS K-7 Disciplines referenced particular concepts such as patterns, time, energy, changes, systems and structure, the inclusion of these concepts within each of the MSS K-7 Disciplines was not found. For example, references to the crosscutting concept of patterns from the NGSS were only found in the MSS Discipline of Earth Science.

While both the NGSS Disciplinary Core Ideas and the MSS Disciplines for K-7 address similar content, variation was found in the application of terms used to address these concepts. For example, though technology, science, and society were mentioned in both the NGSS and MSS, references to links among "engineering, technology, science, and society" were found only in the NGSS. No references to engineering or engineering design were found in the MSS.

Content Comparison Analysis of

NGSS and Michigan's High School Science Essential Content Standards and Expectations

Introduction for High School Comparison

At the high school level, the NGSS were examined using the three dimensions from the National Research Council report: *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (NRC, 2012), which are the foundations of the NGSS; (Scientific and Engineering Practices, Crosscutting Concepts, and Disciplinary Core Ideas) and the MSS High School Science Essential Content Standards and Expectations. The MSS include the disciplines of Physics, Chemistry, Biology and Earth Science. Each of these disciplines addresses the Key Practices of Science Literacy, including Scientific Inquiry, and Reflection and Social Implications.

The framework in Table 4 illustrates the design of the crosswalk for the Next Generation Science Standards and the Michigan High School Science Essential Content Standards and Expectations.

Table 4. Framework for comparison review of the NGSS and MSS High School Science Essential Content Standards and Expectations

NGSS	MSS High School Science Essential Content Standards and Expectations
Scientific and Engineering Practices	⟷ **Key Practices of Science Literacy**
Asking questions and defining problems Developing and using models Planning and carrying out investigations Analyzing and interpreting data Using mathematics and computational thinking Constructing explanations and designing solutions Engaging in argument from evidence Obtaining , evaluating, and communicating information	**Scientific Inquiry:** 1. Generate new questions that can be investigated in the laboratory or field. 2. Critique aspects of scientific investigations. 3. Conduct scientific investigations using appropriate tools and techniques. 4. Identify patterns in data and relate them to theoretical models. 5. Describe a reason for a given conclusion using evidence from an investigation. 6. Explain how scientific evidence supports or refutes claims or explanations of phenomena. 7. Design and conduct a scientific investigation with a hypothesis, several controlled variables, and one manipulated variable. Gather data and organize the results in graphs, tables, and/or charts. **Scientific Reflection and Social Implications:** 1. Critique whether or not specific questions can be answered through scientific investigations. 2. Identify and critique arguments based on scientific evidence. 3. Use appropriate scientific knowledge in social arguments, recognizing their limitations. 4. Gather, synthesize, and evaluate information from multiple sources. 5. Discuss scientific topics in groups, make presentations, summarize what others have said, ask for clarification, take alternative perspectives, and defend a position. 6. Evaluate the future career and occupational prospects of science fields. 7. Explain why a claim or a conclusion is flawed. 8. Critique solutions to problems, given criteria and scientific constraints. 9. Identify scientific tradeoffs in design decisions and choose among alternative solutions. 10. Apply science principles or scientific data to anticipate effects of technological design decisions.
Crosscutting Concept	⟷ **Key Practices of Science Literacy**
Patterns Cause and effect Scale, proportion, and quantity Systems and system models Energy and matter Structure and function Stability and change	**Scientific Inquiry:** 1. Generate new questions that can be investigated in the laboratory or field. 2. Critique aspects of scientific investigations. 3. Conduct scientific investigations using appropriate tools and techniques. 4. Identify patterns in data and relate them to theoretical models. 5. Describe a reason for a given conclusion using evidence from an investigation. 6. Explain how scientific evidence supports or refutes claims or explanations of phenomena. 7. Design and conduct a scientific investigation with a hypothesis, several controlled variables, and one manipulated variable. Gather data and organize the results in graphs, tables, and/or charts. **Scientific Reflection and Social Implications:** 1. Critique whether or not specific questions can be answered through scientific investigations. 2. Identify and critique arguments based on scientific evidence. 3. Use appropriate scientific knowledge in social arguments, recognizing their limitations. 4. Gather, synthesize, and evaluate information from multiple sources. 5. Discuss scientific topics in groups, make presentations, summarize what others have said, ask for clarification, take alternative perspectives, and defend a position. 6. Evaluate the future career and occupational prospects of science fields. 7. Explain why a claim or a conclusion is flawed. 8. Critique solutions to problems, given criteria and scientific constraints. 9. Identify scientific tradeoffs in design decisions and choose among alternative solutions. 10. Apply science principles or scientific data to anticipate effects of technological design decisions.

Table 4. Framework for comparison review of the NGSS and MSS Essential Science Standards for High School (Continued)

NGSS	MSS High School Science Essential Content Standards and Expectations
Disciplinary Core Ideas	**Disciplines**
Physical Sciences: • Matter and its interactions • Motion and Stability: Forces and Interactions • Energy • Waves and their application in Technologies for Information Transfer **Life Sciences:** • From Molecules to Organisms: Structures and Processes • Ecosystems: Interactions, Energy and Dynamics • Heredity: Inheritance and Variation of Traits • Biological Evolution: Unity and Diversity **Earth and Space Sciences:** • Earth's Place in the Universe • Earth's Systems • Earth and Human Activity	**Physics:** • Motion of Objects • Forces and Motion • Forms of Energy and Energy Transformations **Chemistry:** • Forms of Energy • Energy Transfer and Conservation • Properties of Matter • Changes in Matter **Biology:** • Organization and Development of Living Systems • Interdependence of Living Systems and the Environment • Genetics • Evolution and Biodiversity **Earth Science:** • Earth Systems • Solid Earth • Fluid Earth • The Earth in Space in Time
Engineering, Technology and Application of Science: • Defining and Delimiting Engineering Problems • Developing Possible Solutions • Optimizing the Design Solution	**Scientific Reflection and Social Implications:** 1. Critique whether or not specific questions can be answered through scientific investigations. 2. Identify and critique arguments based on scientific evidence. 3. Use appropriate scientific knowledge in social arguments, recognizing their limitations. 4. Gather, synthesize, and evaluate information from multiple sources. 5. Discuss scientific topics in groups, make presentations, summarize what others have said, ask for clarification, take alternative perspectives, and defend a position. 6. Evaluate the future career and occupational prospects of science fields. 7. Explain why a claim or a conclusion is flawed. 8. Critique solutions to problems, given criteria and scientific constraints. 9. Identify scientific tradeoffs in design decisions and choose among alternative solutions. 10. Apply science principles or scientific data to anticipate effects of technological design decisions.

Results of the NGSS and MSS High School Science Essential Content Standards and Expectations Crosswalk Analysis

This section describes the content comparison analysis results and includes the degree of match found between the NGSS and the MSS High School Science Essential Content Standards and Expectations. Similarities, partial matches, and differences are described. A summary is also provided.

NGSS Scientific and Engineering Practices and MSS High School Practices of Science Literacy

NGSS Scientific and Engineering Practices

- Asking questions (for science) and defining problems (for engineering)
- Developing and using models
- Planning and carrying out investigations
- Analyzing and interpreting data
- Using mathematics and computational thinking
- Constructing explanations (for science) and designing solutions (for engineering)
- Engaging in argument from evidence
- Obtaining, evaluating, and communicating information

MSS Key Practices of Science Literacy

1. Scientific Inquiry:

1. Generate new questions that can be investigated in the laboratory or field.
2. Critique aspects of scientific investigations.
3. Conduct scientific investigations using appropriate tools and techniques.
4. Identify patterns in data and relate patterns to theoretical models.
5. Describe a reason for a given conclusion using evidence from an investigation.
6. Explain how scientific evidence supports or refutes claims or explanations of phenomena.
7. Design and conduct a scientific investigation with a hypothesis, several control variables and one manipulated variable. Gather data and organize the results in graphs, tables and/or charts.

2. Scientific Reflection and Social Implications:

1. Critique whether or not specific questions can be answered through scientific investigations.
2. Identify and critique arguments about personal or societal issues based on scientific evidence.

3. Use appropriate scientific knowledge in social arguments, recognizing their limitations.
4. Gather, synthesize, and evaluate information from multiple sources.
5. Discuss scientific topics in groups, make presentations summarize what others have said, ask for clarification, take alternative perspectives, and defend a position.
6. Evaluate why a claim or conclusion is flawed.
7. Critique solutions to problems, given criteria and scientific constraints.
8. Identify scientific tradeoffs in design decisions and choose among alternative solutions.
9. Apply science principles or scientific data to anticipate effects of technological design decisions.

Degree of Match: Low

The NGSS Dimensions of Scientific and Engineering Practices and the MSS High School Practices of Science Literacy were found to have a Low degree of match, based on differences in content.

Similarities: Similarities include references to questions, models, investigations, data, evidence, problems, solutions, argument, evaluating and communicating information.

Differences: Differences exist in the MSS regarding the NGSS references to "Developing and using models," "Analyzing and interpreting data," and "Using mathematics and computational thinking. References to content in engineering, such as "engineering practices," in regard to "designing solutions" were also missing in the MSS.

NGSS Crosscutting Concepts and MSS Key Practices of Science Literacy for High School

1. **Patterns:** Observed patterns of forms and events guide organization and classification, and they prompt questions about relationships and the factors that influence them.
2. **Cause and effect:** Mechanism and explanation. Events have causes, sometimes simple, sometimes multifaceted. A major activity of science is investigating and explaining causal relationships and the mechanisms by which they are mediated. Such mechanisms can then be tested across given contexts and used to predict and explain events in new contexts.
3. **Scale, proportion, and quantity:** In considering phenomena, it is critical to recognize what is relevant at different measures of size, time, and energy and to recognize how changes in scale, proportion, or quantity affect a system's structure or performance.
4. **Systems and system models:** Defining the system under study—specifying its boundaries and making explicit a model of that system—provides tools for understanding and testing ideas that are applicable throughout science and engineering.
5. **Energy and matter:** Flows, cycles, and conservation. Tracking fluxes of energy and matter into, out of, and within systems helps one understand the systems' possibilities and limitations.

6. **Structure and function:** The way in which an object or living thing is shaped and its substructure determine many of its properties and functions.
7. **Stability and change:** For natural and built systems alike, conditions of stability and determinants of rates of change or evolution of a system are critical elements of study.

MSS Key Practices of Science Literacy

1. Scientific Inquiry:

1. Generate new questions that can be investigated in the laboratory or field.
2. Critique aspects of scientific investigations.
3. Conduct scientific investigations using appropriate tools and techniques.
4. Identify patterns in data and relate patterns to theoretical models.
5. Describe a reason for a given conclusion using evidence from an investigation.
6. Explain how scientific evidence supports or refutes claims or explanations of phenomena.
7. Design and conduct a scientific investigation with a hypothesis, several control variables and one manipulated variable. Gather data and organize the results in graphs, tables and/or charts.

2. Scientific Reflection and Social Implications:

1. Critique whether or not specific questions can be answered through scientific investigations.
2. Identify and critique arguments about personal or societal issues based on scientific evidence.
3. Use appropriate scientific knowledge in social arguments, recognizing their limitations.
4. Gather, synthesize, and evaluate information from multiple sources.
5. Discuss scientific topics in groups, make presentations summarize what others have said, ask for clarification, take alternative perspectives, and defend a position.
6. Evaluate why a claim or conclusion is flawed.
7. Critique solutions to problems, given criteria and scientific constraints.
8. Identify scientific tradeoffs in design decisions and choose among alternative solutions.
9. Apply science principles or scientific data to anticipate effects of technological design decisions.

Degree of Match: Low

The NGSS Crosscutting Concepts and MSS Key Practices of Science Literacy for High School were found to have a Low degree of match based on the representation of crosscutting concepts across all of the MSS Key Practices.

Similarities: Both standards address patterns, questions, explanations, science, investigating, explaining, models, tools, and limitations.

Partial Matches: While NGSS states that "a major activity of science is investigating and explaining causal relationships and the mechanisms by which they are mediated," the MSS mention "conduct and critique aspects of scientific investigations."

Differences: No matches were found in MSS Key Practices of Science Literacy regarding references to cause and effect, scale, proportion and quantity, systems, energy and matter, structure and function, and stability and change.

NGSS Disciplinary Core Ideas for High School and the MSS Disciplines for High School

NGSS High School Physical Sciences

- Matter and its interactions
- Motion and Stability: Forces and Interactions
- Energy
- Waves and their application in Technologies for Information Transfer

MSS Disciplines for High School

- Physics
- Chemistry

Degree of Match: Moderate

The NGSS Disciplinary Core Ideas and the MSS Disciplines for High School were found to have a moderate degree of match based on content, however references to engineering were only found in the NGSS.

Similarities: Similar content in the NGSS Physical Sciences Core Ideas was identified in the MSS Physics and Chemistry Disciplines in relation to PS1: Matter and Its Interactions: Structure and Properties of Matter, Chemical Reactions, Nuclear Processes, and Structure and Properties of Matter. and PS3: Energy. Both the NGSS and MSS referenced Energy Transfer.

Partial Matches: Partial matches were found within NGSS PS2: Motion and Stability, in regard to Forces and Interactions, Structure and Properties of Matter, Forces and Motion, Types of Interactions and Definitions of Energy (Electrical Energy). Both the NGSS and MSS reference Energy Transfer. PS4: Waves and Their Applications in Technologies for Information Transfer: Both standards reference the terms Waves, Transfer, Chemical, and Electromagnetic.

Differences: NGSS PS2: Motion and Stability: Stability was not mentioned in the MSS Physical Science Standards. PS3: Energy: Definitions of Energy and Conservation of Energy were not explicitly addressed in the MSS, nor were there references to the relationship between Energy and Forces. Energy in Chemical Processes was not mentioned in the MSS, though references to Chemical Changes and Chemical Bonds were found. PS4: Waves and Their Applications in Technologies for Information Transfer: The MSS standards did not mention Radiation, or Information Technologies and Instrumentation in relation to Physical Science content.

NGSS High School Life Sciences

- From Molecules to Organisms: Structures and Processes
- Ecosystems: Interactions, Energy and Dynamics
- Heredity: Inheritance and Variation of Traits
- Biological Evolution: Unity and Diversity

MSS Disciplines for High School

- Biology

Degree of Match: Moderate

Similarities: Similar contents in the NGSS Life Sciences Disciplinary Core Ideas was found in the MSS in relation to LS1: From Molecules to Organisms: Structures and Processes: Both the NGSS and the MSS mention molecules, organisms, matter, and energy. LS2: Ecosystems: Interactions, Energy and Dynamics: References are made in both sets of standards to Ecosystems, Biodiveristy, and Energy. LS3: Heredity: Inheritance and Variation of Traits: Both standards mention Inheritance and Traits. LS4: Biological Evolution: Unity and Diversity: Both sets of standards address Evolution, Natural Selection and Biodiversity.

Partial Matches: LS2: Ecosystems: Interactions, Energy, and Dynamics: Both standards mention solutions. NGSS includes “Developing Possible Solutions” while MSS mentions “Critique solutions to problems given criteria and scientific constraints.” Interdependent relationships are addressed in the NGSS, while “Interdependence of Living Systems and the Environment” are addressed in the MSS.

Differences: LS1: From Molecules to Organisms: Structures and Processes: No matches were found with Structure and Function in the MSS Biology. LS2: Ecosystems: No references were found that reference Relationships, Interactions, Group Behavior, Cycles of Matter, Dynamics, Functioning, Resilience, or Chemical Processes. LS3: Heredity: Inheritance and Variation of Traits: No matches were found with Structure and Function and Variation. LS4: Biological Evolution: Unity and Diversity: No matches were found with Evidence of Common Ancestry and Diversity, Adaptations or Humans.

NGSS High School Earth and Space Sciences

- Earth's Place in the Universe
- Earth's Systems Earth and
- Human Activity

MSS Disciplines

- Earth Science

Degree of Match: Moderate

Similarities: Both the NGSS Earth and Space Sciences and the MSS Earth Science standards address Earth, History, Systems, Plate Tectonics, Weather, Climate, Human Impacts, and Climate Change.

Partial Matches: ESS1: Earth's Place in the Universe: Both sets of standards mention systems; however, only the NGSS mentions the Solar System. History is mentioned in both standards, but only NGSS mentions History of Planet Earth. ESS2: Earth's Systems: Both sets of standards mention Earth and Systems, but only NGSS references Earth Materials, the Role of Water in the Earth's Surfaces, and Large-Scale System Interactions. ESS3: Earth and Human Activity: Resources are mentioned in both sets of standards, but only NGSS references Natural Resources. Climate Change is referenced in both standards, but only NGSS references Global Climate Change.

Differences: ESS1: Earth's Place in the Universe: No matches were found in the MSS regarding the Universe and Its Stars. ESS2: Earth's Systems: No matches were found with Biogeology. ESS3: Earth and Human Activity: No matches were found with Natural Hazards.

High School Engineering, Technology and Applications of Science

- Defining and Delimiting Engineering Problems
- Developing Possible Solutions
- Optimizing the Design Solution

MSS Key Practices of Science Literacy

1. Scientific Reflection and Social Implications:

1. Critique whether or not specific questions can be answered through scientific investigations.
2. Identify and critique arguments about personal or societal issues based on scientific evidence.
3. Use appropriate scientific knowledge in social arguments, recognizing their limitations.
4. Gather, synthesize, and evaluate information from multiple sources.

5. Discuss scientific topics in groups, make presentations summarize what others have said, ask for clarification, take alternative perspectives, and defend a position.
6. Evaluate why a claim or conclusion is flawed.
7. Critique solutions to problems, given criteria and scientific constraints.
8. Identify scientific tradeoffs in design decisions and choose among alternative solutions.
9. Apply science principles or scientific data to anticipate effects of technological design decisions.

Degree of Match: Low

Similarities: Both sets of standards mention Problems, Solutions and Design.

Partial Match: Both standards mention Problems, Design, and Solutions, however, only the MSS mention technological design, while only the NGSS reference Optimizing the Design Solution.

Differences: The MSS standards do not mention Engineering or Defining and Delimiting Engineering Problems.

Summary

The NGSS and MSS Essential Standards for High School were found to have a Moderate overall degree of match. See Table 5 below for results in each category of comparison.

Table 5. Results of the NGSS and the MSS High School Science Essential Content

Next Generation Science Standards	Michigan Science Standards High School	Degree of Match
Scientific and Engineering Practices	Key Practices of Science Literacy	Low Match
NGSS Crosscutting Concepts	Key Practices of Science Literacy	Low Match
NGSS Disciplinary Core Ideas	MSS Disciplines for High School	Moderate Match
Overall Degree of Match		**Low to Moderate Match**

Standards and Expectations Comparison Analysis

Both the NGSS Science and Engineering Practices and MSS High School Key Practices of Science Literacy covered content regarding scientific investigations. However, only the NGSS includes references to “Developing and using models,” “Analyzing and interpreting data,” and “Using mathematics and computational thinking.” References to “engineering practices,” in regard to “designing solutions” were not identified in the MSS.

The NGSS Crosscutting Concepts were found to have a Low degree of match with the MSS Key Practices of Scientific Literacy (Scientific Inquiry, and Reflection and Social Implications). Though similarities were found in regard to references to patterns, models, and scientific investigations, the inclusion of these concepts across all of the MSS Key Practices of Science Literacy for high school was not found. Specifically, the MSS Key Practices do not mention cause and effect, scale, proportion and quantity, systems, energy and matter, structure and function, and stability and change.

The NGSS Disciplinary Core Ideas for High School and the MSS Disciplines for High School address similar content with a few significant exceptions. The MSS standards do not mention Engineering or Defining and Delimiting Engineering Problems. In addition, the NGSS standards do not address concepts related to Chemistry in the same way or to the degree that they are addressed in the MSS Disciplines for High School.

Description of the Unique Features of the NGSS

Introduction

This analysis included an in-depth examination of some of the unique features that were found only in the NGSS. A description of these unique features is included below, in response to the following question:

1 To what extent would the adoption of the NGSS represent an improvement over current Michigan Science Standards, based on the *Framework for K-12 Science Education* (NRC, 2012)?

The Next Generation Science Standards offer an added value to the MSS. While the MSS and NGSS overlap in some content areas, examples of NGSS features that were not found in the MSS Grade Level Content Expectations for K-7 or the High School Essential Content Standards and Content Expectations include:

- The NGSS science concepts build coherently from grade to grade, while implementing crosscutting concepts that are integrated within core content. These crosscutting concepts connect concepts and content across all science disciplines. For example, Science and Engineering are integrated in the NGSS from K-12.

- The NGSS provide progressions across grade bands for the Earth and Space Sciences, Life Sciences and Physical Sciences.

- The NGSS are aligned with the Common Core State Standards in English Language Arts and Mathematics.

- The NGSS provide performance expectations in new content areas such Engineering, which is defined and integrated with Science and Technology in the NGSS from K-12.

Coherence

A key aspect of the NGSS Disciplinary Core Ideas is that they build on each other across grade bands. The NGSS provide linkages between these Disciplinary Core Ideas and seven Crosscutting Concepts. The Crosscutting Concepts help students to deepen their understanding of the Disciplinary Core Ideas (see *Framework* (NRC, 2012), Appendix G, page 83) and include:

- Patterns
- Cause and effect
- Scale, proportion, and quantity
- Energy and matter
- Structure and function
- Stability and change

The *Framework* (NRC, 2012) emphasizes that these concepts need to be explicitly stated for students in order to provide a schema for interrelating knowledge from various science fields into a coherent and scientifically based view of the world (http://www.nextgenscience.org/next-generation-science-standards).

Progressions

The NGSS provide content expectations for students in kindergarten through high school that build on the Disciplinary Core Idea Learning Progressions. These progressions provide a reference that depicts the content in each grade band. The full progressions are outlined in the *Framework* (NRC, 2012). Progressions provide examples of how increases in the sophistication of students' thinking are addressed across grades in the Earth and Space Sciences, Life Sciences and Physical Sciences. Table 6 illustrates a Physical Science Progression that increases in sophistication across grade bands:

Table 6. Example of NGSS Physical Science progression across grade bands for K-12

NGSS Disciplinary Core Idea	Grades K-2	Grades 3-5	Grades 6-8	Grades 9-12
PS1.B Chemical Reactions	Heating and cooling substances cause changes that are sometimes reversible and sometimes not.	Chemical reactions that occur when substances are mixed can be identified by the emergence of substances with different properties; the total mass remains the same.	Reacting substances rearrange to form different molecules, but the number of atoms is conserved. Some reactions release energy and others absorb energy.	Chemical processes are understood in terms of collisions of molecules, rearrangement of atoms, and changes in energy as determined by properties of elements involved

Common Core State Standards

The Common Core State Standards (CCSS) in Mathematics and English Language Arts align with the NGSS in many areas, such as pacing. This was by design, as the NGSS development team worked with the CCSS for Mathematics writing team and the CCSS English Language Arts writing team to ensure that the NGSS are consistent with the grade-by-grade standards in the CCSS-ELA and CCSS-M. The NGSS Appendix L and Appendix M provide explicit connections to both CCSS Mathematics and English Language Arts standards. Table 7 displays an example of a CCSS ELA Anchor Standard for writing and an NGSS Science and Engineering Practice.

Table 7. Example of Common Core English Language Arts Anchor Standard and NGSS Science and Engineering Practice

NGSS Disciplinary Core Idea	Grades K-2
CCR Writing Anchor #7: Conduct short as well as more sustained research projects based on focused questions, demonstrating understanding of the subject under investigation	"Asking Questions and Defining Problems" requires that students at any grade level should be able to ask questions of each other about the texts they read, the features of the phenomena they observe, and the conclusions they draw from their models or scientific investigations. For engineering, they should ask questions to define the problem to be solved and to elicit ideas that lead to the constraints and specifications for its solution. (NRC Framework 2011, p. 56).

New Content

The NGSS includes new content that is not currently in the MSS. One example is the inclusion of content that emphasizes engineering. In the NGSS, engineering is addressed in both the Scientific and Engineering Practices and in the Disciplinary Core ideas of Engineering, Technology and Applications of Science. The rationale for providing students with a foundation in engineering design is based on the idea that engineering design allows them to engage in and solve major societal and environmental challenges (Appendix I-Engineering Design in the NGSS).

Engineering design is similar to scientific inquiry, which is part of the current MSS Grade Level Content Standards and the Michigan High School Science Essential Content Standards and Expectations . However, the NGSS distinguishes between these important concepts. According to the NGSS, scientific inquiry involves the formulation of a question that can be answered through investigation, while engineering design involves the formulation of a problem that can be solved through design. By integrating engineering design into the structure of science education, the NGSS provide students with the tools to engage in solving future environmental and societal challenges (Appendix I-Engineering Design in the NGSS).

The NGSS Scientific and Engineering Practices include a focus on new content such as "Developing and using models." Exposure to this content is expected to help prepare students for careers in fields that require knowledge of science, technology, engineering and mathematics. According to the *Framework* (NRC, 2012), "Modeling can begin in the earliest grades, with students' models progressing from concrete "pictures" and/or physical scale models (e.g., a toy car) to more abstract representations of relevant relationships in later grades, such as a diagram representing forces on a particular object in a system" (NRC, 2012, p. 58). Table 8 provides an example of how the NGSS Scientific and Engineering Practice of "Developing and Using Models" can be applied across grades.

Table 8. Example of NGSS Scientific and Engineering modeling progression across grade bands for K -12

Grades K-2	Grades 3-5	Grades 6-8	Grades 9-12
Modeling in K–2 builds on prior experiences and progresses to include using and developing models (i.e., diagram, drawing, physical replica, diorama, dramatization, or storyboard) that represent concrete events or design solutions.	Modeling in 3–5 builds on K–2 experiences and progresses to building and revising simple models and using models to represent events and design solutions.	Modeling in 6–8 builds on K–5 experiences and progresses to developing, using, and revising models to describe, test, and predict more abstract phenomena and design systems.	Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds.

The core idea of Engineering Design includes three component ideas:

A. Defining and delimiting engineering problems involves stating the problem to be solved as clearly as possible in terms of criteria for success, and constraints or limits.

B. Designing solutions to engineering problems begins with generating a number of different possible solutions, and then evaluating potential solutions to see which ones best meet the criteria and constraints of the problem.

C. Optimizing the design solution involves a process in which solutions are systematically tested and refined and the final design is improved by trading off less important features for those that are more important (NRC, 2012).

Table 9 presents an example of how these engineering core ideas can be applied across grade bands (see Appendix I: Engineering Design in the NGSS).

Table 9. Example of Engineering Design in the NGSS across grade bands for K-12

Grades K-2	Grades 3-5	Grades 6-8	Grades 9-12
Engineering design in the earliest grades introduces students to "problems" as situations that people want to change. They can use tools and materials to solve simple problems, use different representations to convey solutions, and compare different solutions to a problem and determine which is best. Students in all grade levels are not expected to come up with original solutions, although original solutions are always welcome. Emphasis is on thinking through the needs or goals that need to be met, and which solutions best meet those needs and goals.	At the upper elementary grades, engineering design engages students in more formalized problem solving. Students define a problem using criteria for success and constraints or limits of possible solutions. Students research and consider multiple possible solutions to a given problem. Generating and testing solutions also becomes more rigorous as the students learn to optimize solutions by revising them several times to obtain the best possible design.	At the middle school level, students learn to sharpen the focus of problems by precisely specifying criteria and constraints of successful solutions, taking into account not only what needs the problem is intended to meet, but also the larger context within which the problem is defined, including limits to possible solutions. Students can identify elements of different solutions and combine them to create new solutions. Students at this level are expected to use systematic methods to compare different solutions to see which best meet criteria and constraints, and to test and revise solutions a number of times in order to arrive at an optimal design.	Engineering design at the high school level engages students in complex problems that include issues of social and global significance. Such problems need to be broken down into simpler problems to be tackled one at a time. Students are also expected to quantify criteria and constraints so that it will be possible to use quantitative methods to compare the potential of different solutions. While creativity in solving problems is valued, emphasis is on identifying the best solution to a problem, which often involves researching how others have solved it before. Students are expected to use mathematics and/or computer simulations to test solutions under different conditions, prioritize criteria, consider trade-offs, and assess social and environmental impacts.

Part of this review includes an examination of the resources that are being developed and already available to support science education aligned with the NGSS. The response to question 2 below addresses this issue:

2 What are the opportunities for implementation support?

Resources to support the implementation of the NGSS have been and continue to be developed by the Council for Chief State School Officers, Achieve, and the NGSS Network of States. Examples of these resources are provided in Table 10.

Table 10. Resources to support NGSS implementation

Resource	Resource Description	Timeline
NGSS Evidence Statements	Statements of observable and measurable components of NGSS.	Coming in 2014
NGSS Accelerated Model Course Pathways	Examples of how the NGSS can be tailored for accelerated students, developed by Advanced Placement teachers.	Coming in 2014
NGSS Model Content Frameworks	Examples for curricula developers of how the NGSS could be organized over the course of the school year and across grade levels.	Coming in 2014
Research and resources related to English Language Learners, Language and Literacy	Stanford University recently released 13 papers on a variety of issues related to language and literacy in the content areas of CCSS and NGSS (Stanford University,(2011). Understanding language.	Retrieved from http://ell.stanford.edu/publication/language-demands-and-opportunities-relation-next-generation-science-standards-ells
Sample NGSS Classroom Assessment Tasks	Teacher-developed sample tasks that blend content, practices, and concepts from both the NGSS and the Common Core State Standards.	Coming in 2014
Sample NGSS Classroom Assessment	Teacher-developed sample tasks that blend content, practices and concepts from both the NGSS and the Common Core State Standards.	Coming in 2014

Challenges involved in change can be anticipated and addressed through planning, support, and use of resources. The following section addresses this issue through answers to question 3:

3 What are some suggestions for how any weaknesses inherent with a NGSS adoption could be compensated for in implementation planning?

One of the challenges inherent to the adoption of the NGSS is transitioning from current teaching practice of the MSS, to delivering instruction in new content area. Fortunately, a number of resources exist and are under development to support this transition (see Table 10). For example, the NGSS Network allows member states to participate in the development of NGSS resources that can be shared.

Maximizing the services of Michigan's science experts for professional development, advisement, and support is another strategy that will help to alleviate the transition of new science standards. An on-going professional development plan that incorporates this expertise will enhance access to instructional support for Michigan's educators.

Since the MSS Grade Level Content Expectations for K-7 and High School Science Essential Content Standards and Expectations include many of the concepts addressed in the NGSS, a plan to phase in the unique concepts specific to the NGSS will support teachers in the transition from the current standards. An NGSS Implementation Plan that includes a timeline for assessment development, professional development, and course development for high school science credits is recommended. The crosswalks developed for this analysis (see Appendix I and Appendix II) could be used to support this effort.

Recommendations

Based on the compelling evidence from this content comparison analysis, the recommendations in Table 11 were formulated, along with a rationale for each recommendation.

Table 11. Recommendations and Rationales

Recommendations	Rationales
Michigan should consider the adoption of the NGSS performance expectations, in order to improve science education in all grades.	The value added by the adoption of the NGSS includes access to current science concepts that are required to prepare students for college and careers.
The NGSS Science and Engineering Practices and Crosscutting Concepts should be implemented to enhance current science education instruction for grades K-12.	The NGSS Science and Engineering Practices and Crosscutting Concepts are embedded across the NGSS performance expectations and provide coherence across grades and all science disciplines.
The NGSS performance expectations for the Disciplinary Core Ideas in Engineering, Technology and Application of Science contain new content that should be included in science instruction across all grades.	Implementation of the NGSS performance expectations in new content areas such Engineering, Technology and the Application of Science will prepare students for solving future and current societal problems.
The NGSS performance expectations provide explicit connections to Common Core Mathematics and English Language Arts Standards that should be integrated into science instruction.	The NGSS linkages to the Common Core Standards for Mathematics and English Language Arts connect consistent performance expectations across core content areas.
NGSS Professional Development Resources that support instruction in new content areas are available through participation in the NGSS Network and should be leveraged to support Michigan science teachers.	On-going, high quality professional development that includes current science concepts is essential to improvements in science instruction.
NGSS resources for formative and summative assessment development should be utilized by Michigan science teachers to support classroom instruction.	Teachers' use of standards- aligned, formative and summative assessments is critical to science instruction.

References

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Appendix I

Crosswalk with NGSS and Michigan's Science Grade Level Content Standards

K–7 Crosswalk

The Michigan Department of Education (MDE) and Wayne Regional Education Service Agency contracted with SRI International's Center for Technology in Learning to conduct an external, independent content comparison review of the Michigan Science Standards (MSS) and the Next Generation Science Standards (NGSS). This review includes the development of two crosswalks: the first focuses on the Michigan Science Grade Level Content Expectations for Grades K-7 and NGSS, while the second crosswalk compares the MSS High School Science Essential Content Standards and Expectations and the NGSS for High School. The crosswalks depict similarities and differences between the standards. An analysis of these crosswalk results was used to complete the content comparison of these sets of standards (see Part I of this report).

Methodology

An initial examination of the standards was conducted using the three dimensions from the National Research Council's report: *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (2011), which are the foundations of the NGSS; (Scientific and Engineering Practices, Crosscutting Concepts, and Disciplinary Core Ideas) and the MSS as outlined in the Science Grade Level Content Expectations for K-7 and the High School Science Essential Content Standards and Expectations. A crosswalk framework was created for each comparison review (see Tables A2 and A4) that defines the areas in each set of standards to be compared. A scale was developed that describes the degree of match between the content areas to be compared (Tables A1 and A5).

Table A1. Criteria for rating the degree of match between the NGSS and the MSS

Criteria for Match Between Comparison Categories on Standards	Degree of Match Between Standard Categories
No identified match	No Match
A few matches between concepts and terms	Low Match
Some matches between concepts and terms	Low to Moderate
Several matches between concepts and terms	Moderate Match
Most concepts and terms match	High Match

Structure of the Crosswalk for NGSS and MSS Grade Level Content Expectations for K-7

The framework in Table A2 illustrates the design of the crosswalk for the Next Generation Science Standards and the MSS Grade Level Content Expectations for grades K-7. The first column describes the three dimensions addressed by the NGSS; Scientific and Engineering Practices, Crosscutting Concepts, and Disciplinary Core Ideas. The Disciplinary Core Ideas include four Domains: Physical Sciences, Life Sciences, Earth and Space Sciences, and Engineering, Technology, and Applications of Science. The second column describes the four disciplines of the MSS Grade Level Content Expectations for grades K-7, which include: Science Processes, Physical Science, Life Science, and Earth Science. The MSS Science Processes of Inquiry Analysis and Communication, and Reflection, and Social Implications are compared to the NGSS Scientific and Engineering Practices and the Disciplinary Core Ideas of Engineering, Technology and Application of Science. The MSS Disciplines of Physical Science, Life Science and Earth Science are compared to both the NGSS Crosscutting Concepts and the Disciplinary Core Ideas.

Table A2: Framework for comparison review of the NGSS and MSS for grades K-7

NGSS		MSS
Scientific and Engineering Practices	⟷	**Science Processes**
Asking questions and defining problems Developing and using models Planning and carrying out investigations Analyzing and interpreting data Using mathematics and computational thinking Constructing explanations and designing solutions Engaging in argument from evidence Obtaining, evaluating, and communicating information		Inquiry Process Inquiry Analysis and Communication Reflection, and Social Implications
Crosscutting Concept	⟷	**Disciplines**
Patterns Cause and effect Scale, proportion, and quantity Systems and system models Energy and matter Structure and function Stability and change		Physical Science Force and Motion Energy Properties of Matter Life Science: Organization of Living Things Heredity Evolution Ecosystems Earth Science Earth Systems Solid Earth Fluid Earth Earth in Space and Time
Disciplinary Core Ideas	⟷	**Disciplines (all of the above)**
Physical Sciences Life Sciences Earth and Space Sciences		Physical Science Life Science Earth Science
Disciplinary Core Ideas	⟷	**Science Processes**
Engineering, Technology and Application of Science		Inquiry Reflection, and Social Implications

The Crosswalk in Table A3 illustrates the content comparison for the NGSS and MSS Grade Level Content Expectations for K-7. Concepts and terms that were determined to be similar in both the MSS and the NGSS were color coded in Table A3 to indicate a match. *While the color chosen does not have any particular significance, the amount of color indicates the degree of similarity. Ratings for the degree of match found are described in column 3 of Table A3. An overall degree of match is provided in the last row of the crosswalk.*

Table A3. Crosswalk of the NGSS and the MSS Grade Level Content Expectations K-7

NGSS Dimensions	MSS Disciplines	Degree of Match
Scientific and Engineering Practices 1. Asking questions (for science) and defining problems (for engineering) 2. Developing and using models 3. Planning and carrying out investigations 4. Analyzing and interpreting data 5. Using mathematics and computational thinking 6. Constructing explanations (for science) and designing solutions (for engineering) 7. Engaging in argument from evidence 8. Obtaining, evaluating, and communicating information	**Science Processes:** K-7 Inquiry Process: Develop an understanding that scientific inquiry and reasoning involves observing, questioning, investigating, recording, and developing solutions to problems. **Inquiry Analysis and Communication:** Develop an understanding that scientific inquiry and investigations require analysis and communication of findings, using appropriate technology. Inquiry includes an analysis and presentation of findings that lead to future questions, research, and investigations. **K-7 Reflection, and Social Implications:** Develop an understanding that claims and evidence for their scientific merit should be analyzed. Understand how scientists decide what constitutes scientific knowledge. Develop an understanding of the importance of reflection on scientific knowledge and its application to new situations to better understand the role of science in society and technology.	**Low Match** found for NGSS Scientific Practices with MSS Science Processes **No Match** found for NGSS Engineering with MSS

Table A3. Crosswalk of the NGSS and the MSS Grade Level Content Expectations K-7 (Continued)

NGSS: Crosscutting Concepts:	MSS Disciplines		Degree of Match
1. Patterns: Observed patterns of forms and events guide organization and classification, and they prompt questions about relationships and the factors that influence them. **2. Cause and effect:** Mechanism and explanation. Events have causes, sometimes simple, sometimes multifaceted. A major activity of science is investigating and explaining causal relationships and the mechanisms by which they are mediated. Such mechanisms can then be tested across given contexts and used to predict and explain events in new contexts. **3. Scale, proportion, and quantity:** In considering phenomena, it is critical to recognize what is relevant at different measures of size, time, and energy and to recognize how changes in scale, proportion, or quantity affect a system's structure or performance. **4. Systems and system models.** Defining the system under study—specifying its boundaries and making explicit a model of that system—provides tools for understanding and testing ideas that are applicable throughout science and engineering. **5. Energy and matter:** Flows, cycles, and conservation. Tracking fluxes of energy and matter into, out of, and within systems helps one understand the systems' possibilities and limitations. **6. Structure and function.** The way in which an object or living thing is shaped and its substructure determine many of its properties and functions. **7. Stability and change.** For natural and built systems alike, conditions of stability and determinants of rates of change or evolution of a system are critical elements of study.	**Physical Science** **Force and Motion** a. Position b. Gravity c. Force d. Speed e. Force Interactions **Energy** a. Forms of Energy b. Light Properties c. Sound d. Energy and Temperature e. Electrical Circuits f. Kinetic Potential Energy g. Waves and Energy h. Energy Transfer i. Solar Energy Effects **Properties of Matter** a. Physical Properties b. States of Matter Magnet c. Material d. Composition e. Conductive and Reflective Properties f. Chemical Properties g. Elements and Compounds Changes in Matter: a. Changes in State Chemical Changes **Life Science : Organization of Living Things** a. Life Requirements b. Life Cycles c. Structures and Functions d. Classification e. Cell Functions f. Growth and Development g. Animal Systems h. Producers, Consumers, and Decomposers i. Photosynthesis **Heredity** a. Observable b. Characteristics c. Inherited and Acquired Traits d. Reproduction	**Evolution** a. Environmental Adaptation b. Survival c. Species Adaptation and Survival d. Relationships among Organisms **Ecosystems:** d. Interactions e. Changed Environment f. Effects g. Interactions of Organisms h. Relationships of Organisms i. Biotic and Abiotic Factors j. Environmental Impact of Organisms **Earth Science:** **Earth Systems** a. Solar Energy b. Weather c. Weather Measurement d. Natural Resources e. Human Impact f. Human Consequences g. Seasons h. Weather and Climate i. Water Cycle **Solid Earth** a. Earth Materials b. Surface Changes c. Using Earth d. Materials e. Soil f. Rock Formation g. Plate Tectonics h. Magnetic Field of Earth	**Low Match** found for NGSS Cross-Cutting Concepts across all of the MSS Disciplines for grades K-7

Table A3. Crosswalk of the NGSS and the MSS Grade Level Content Expectations K-7 (Continued)

		Fluid Earth a. Water b. Water Movement c. Atmosphere **Earth in Space and Time** a. Characteristics of Objects in the Sky b. Patterns of Objects in the Sky c. Fossils d. Solar System Motion e. Fossils k. Geologic Time	
NGSS Disciplinary Core Ideas: Domains 1-4	**MSS Disciplines 2-4**		**Degree of Match**
Domain 1. Physical Sciences: • Matter and its interactions • Motion and stability: Forces and interactions • Energy • Waves and their applications in technologies for information transfer	**Physical Science:** **Force and Motion:** a. Position b. Gravity c. Force d. Speed e. Force Interactions **Energy:** a. Forms of Energy b. Light Properties c. Sound d. Energy and Temperature e. Electrical Circuits f. Kinetic Potential Energy g. Waves and Energy h. Energy Transfer i. Solar Energy Effects **Properties of Matter:** a. Physical Properties b. States of Matter c. Magnet d. Material e. Composition f. Conductive and Reflective Properties g. Chemical Properties h. Elements and Compounds **Changes in Matter:** a. Changes in State b. Chemical Changes		**Moderate Match** found for NGSS Disciplinary Core Ideas and the MSS Disciplines for grades K-7

Table A3. Crosswalk of the NGSS and the MSS Grade Level Content Expectations K-7 (Continued)

Domain 2: Life Sciences • From molecules to organisms: Structures and processes • Ecosystems: Interactions, energy, and dynamics • Heredity: Inheritance and variation of traits • Biological evolution: Unity and diversity	**Life Science** **Organization of Living Things** a. Life Requirements b. Life Cycles c. Structures and Functions d. Classification e. Cell Functions f. Growth and Development g. Animal Systems h. Producers, Consumers, and Decomposers i. Photosynthesis **Heredity:** a. Observable b. Characteristics c. Inherited and Acquired Traits d. Reproduction **Evolution:** a. Environmental Adaptation b. Survival c. Species Adaptation and Survival d. Relationships among Organisms **Ecosystems:** a. Interactions b. Changed Environment c. Effects d. Interactions of Organisms e. Relationships of Organisms f. Biotic and Abiotic Factors g. Environmental Impact of Organisms	**Moderate Match** found between NGSS Life Sciences and MSS Life Science
Domain 3. Earth and Space Sciences: • Earth's place in the universe • Earth's systems • Earth and human activity	**Discipline 4: Earth Science:** a. Solar Energy b. Weather c. Weather Measurement d. Natural Resources e. Human Impact f. Human Consequences g. Seasons h. Weather and Climate i. Water Cycle **Solid Earth** a. Earth Materials b. Surface Changes c. Using Earth d. Materials e. Soil f. Rock Formation g. Plate Tectonics h. Magnetic Field of Earth **Fluid Earth** a. Water b. Water Movement c. Atmosphere **Earth in Space and Time** a. Characteristics of Objects in the Sky b. Patterns of Objects in the Sky c. Fossils d. Solar System Motion e. Geologic Time	**Moderate Match** found between NGSS Earth and Space Sciences and MSS Earth Science

Table A3. Crosswalk of the NGSS and the MSS Grade Level Content Expectations K-7 (Continued)

Domain 4. Engineering, Technology, and Applications of Science • Engineering design • Links among engineering, technology, science and society	**K-7 Inquiry Analysis and Communication: Standard S.IA:** Develop an understanding that scientific inquiry and investigations require analysis and communication of findings, using appropriate technology. Inquiry includes an analysis and presentation of findings that lead to future questions, research, and investigations. **Reflection, and Social Implications:** **K-7 Standard S.RS:** Develop an understanding that claims and evidence for their scientific merit should be analyzed. Understand how scientists decide what constitutes scientific knowledge. Develop an understanding of the importance of reflection on scientific knowledge and its application to new situations to better understand the role of science in society and technology.	**Low Match** found with NGSS Technology and Applications of Science and MSS Inquiry Analysis and Communication and Reflection and Social Implications **No Match** found for NGSS Engineering with MSS
Overall degree of match		**Low to Moderate**

Appendix II

Crosswalk with NGSS and Michigan's High School Science Essential Content Standards and Expectations

High School Crosswalk

A content comparison of the NGSS for High School and the MSS High School Science Essential Content Standards and Expectations was conducted by SRI International's Center for Technology in Learning, in order to determine the similarities and differences between these two sets of standards. A crosswalk was developed that depicts the results of this review (see Table A6).

Structure of Crosswalk for NGSS and MSS High School Science Essential Content Standards and Expectations

The framework in Table A4 illustrates the content used in the comparison between the Next Generation Science Standards and the MSS High School Science Essential Content Standards and Expectations . The first column describes the three dimensions of the NGSS from the National Research Council's report: *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (2011), which are the foundations of the NGSS; Scientific and Engineering Practices, Crosscutting Concepts, and Disciplinary Core Ideas. The Disciplinary Core Ideas include four Domains: Physical Sciences, Life Sciences, Earth and Space Sciences, and Engineering, Technology, and Applications of Science. The second column describes the disciplines of the MSS High School Science Essential Content Standards and Expectations, which includes Physics, Chemistry, Biology and Earth Science. Each of these disciplines addresses the Key Practices of Science Literacy; Scientific Inquiry and Reflection and Social Implications. These concepts were compared to the NGSS Scientific and Engineering Practices and the Crosscutting Concepts. Note that the content in the NGSS Physical Sciences was compared to the MSS content for both Physics and Chemistry, while the NGSS domain of Engineering, Technology, and Applications of Science was compared to the MSS Key Practices of Scientific Reflection and Social Implications.

Table A4. Framework for comparison review of the NGSS and MSS High School Science Essential Content Standards and Expectations

NGSS	MSS High School Science Essential Content Standards and Expectations
Scientific and Engineering Practices ⟷	**Key Practices of Science Literacy**
Asking questions and defining problems Developing and using models Planning and carrying out investigations Analyzing and interpreting data Using mathematics and computational thinking Constructing explanations and designing solutions Engaging in argument from evidence Obtaining , evaluating, and communicating information	**Scientific Inquiry:** 1. Generate new questions that can be investigated in the laboratory or field. 2. Critique aspects of scientific investigations. 3. Conduct scientific investigations using appropriate tools and techniques. 4. Identify patterns in data and relate them to theoretical models. 5. Describe a reason for a given conclusion using evidence from an investigation. 6. Explain how scientific evidence supports or refutes claims or explanations of phenomena. 7. Design and conduct a scientific investigation with a hypothesis, several controlled variables, and one manipulated variable. Gather data and organize the results in graphs, tables, and/or charts. **Scientific Reflection and Social Implications:** 1. Critique whether or not specific questions can be answered through scientific investigations. 2. Identify and critique arguments based on scientific evidence. 3. Use appropriate scientific knowledge in social arguments, recognizing their limitations. 4. Gather, synthesize, and evaluate information from multiple sources. 5. Discuss scientific topics in groups, make presentations, summarize what others have said, ask for clarification, take alternative perspectives, and defend a position. 6. Evaluate the future career and occupational prospects of science fields. 7. Explain why a claim or a conclusion is flawed. 8. Critique solutions to problems, given criteria and scientific constraints. 9. Identify scientific tradeoffs in design decisions and choose among alternative solutions. 10. Apply science principles or scientific data to anticipate effects of technological design decisions.
Crosscutting Concept ⟷	**Key Practices of Science Literacy**
Patterns Cause and effect Scale, proportion, and quantity Systems and system models Energy and matter Structure and function Stability and change	**Scientific Inquiry:** 1. Generate new questions that can be investigated in the laboratory or field. 2. Critique aspects of scientific investigations. 3. Conduct scientific investigations using appropriate tools and techniques. 4. Identify patterns in data and relate them to theoretical models. 5. Describe a reason for a given conclusion using evidence from an investigation. 6. Explain how scientific evidence supports or refutes claims or explanations of phenomena. 7. Design and conduct a scientific investigation with a hypothesis, several controlled variables, and one manipulated variable. Gather data and organize the results in graphs, tables, and/or charts. **Scientific Reflection and Social Implications:** 1. Critique whether or not specific questions can be answered through scientific investigations. 2. Identify and critique arguments based on scientific evidence. 3. Use appropriate scientific knowledge in social arguments, recognizing their limitations. 4. Gather, synthesize, and evaluate information from multiple sources. 5. Discuss scientific topics in groups, make presentations, summarize what others have said, ask for clarification, take alternative perspectives, and defend a position. 6. Evaluate the future career and occupational prospects of science fields. 7. Explain why a claim or a conclusion is flawed. 8. Critique solutions to problems, given criteria and scientific constraints. 9. Identify scientific tradeoffs in design decisions and choose among alternative solutions. 10. Apply science principles or scientific data to anticipate effects of technological design decisions.

Table A4. Framework for comparison review of the NGSS and MSS High School Science Essential Content Standards and Expectations (Continued)

NGSS	MSS High School Science Essential Content Standards and Expectations
Disciplinary Core Ideas ⟷	**Disciplines**
Physical Sciences: • Matter and its interactions • Motion and Stability: Forces and Interactions • Energy • Waves and their application in Technologies for Information Transfer **Life Sciences:** • From Molecules to Organisms: Structures and Processes • Ecosystems: Interactions, Energy and Dynamics • Heredity: Inheritance and Variation of Traits • Biological Evolution: Unity and Diversity **Earth and Space Sciences:** • Earth's Place in the Universe • Earth's Systems • Earth and Human Activity	**Physics:** • Motion of Objects • Forces and Motion • Forms of Energy and Energy Transformations **Chemistry:** • Forms of Energy • Energy Transfer and Conservation • Properties of Matter • Changes in Matter **Biology:** • Organization and Development of Living Systems • Interdependence of Living Systems and the Environment • Genetics • Evolution and Biodiversity **Earth Science:** • Earth Systems • Solid Earth • Fluid Earth • The Earth in Space in Time
Engineering, Technology and Application of Science: • Defining and Delimiting Engineering Problems • Developing Possible Solutions • Optimizing the Design Solution	**Scientific Reflection and Social Implications:** 1. Critique whether or not specific questions can be answered through scientific investigations. 2. Identify and critique arguments based on scientific evidence. 3. Use appropriate scientific knowledge in social arguments, recognizing their limitations. 4. Gather, synthesize, and evaluate information from multiple sources. 5. Discuss scientific topics in groups, make presentations, summarize what others have said, ask for clarification, take alternative perspectives, and defend a position. 6. Evaluate the future career and occupational prospects of science fields. 7. Explain why a claim or a conclusion is flawed. 8. Critique solutions to problems, given criteria and scientific constraints. 9. Identify scientific tradeoffs in design decisions and choose among alternative solutions. 10. Apply science principles or scientific data to anticipate effects of technological design decisions.

Concepts and terms that were similar in both the Next Generation Science Standards and the Michigan High School Science Essential Content Standards and Expectations were color coded to indicate a match. *While the color chosen does not have any particular significance, the amount of color indicates the degree of similarity. Ratings for the degree of match are described in Table A5 below.*

Table A5. Criteria for rating the degree of match between the NGSS and the MSS

Criteria for Match Between Comparison Categories on Standards	Degree of Match Between Standard Categories
No identified match	No Match
A few matches between concepts and terms	Low Match
Some matches between concepts and terms	Low to Moderate
Several matches between concepts and terms	Moderate Match
Most concepts and terms match	High Match

The crosswalk in Table A6 depicts the content comparison between the NGSS and the MSS High School Science Essential Content Standards and Expectations. The third column describes the degree of match between the two sets of standards, as determined by the scale in Table A5. *An overall degree of match is provided in the last row of the crosswalk.*

Table A6. Crosswalk of the NGSS and MSS High School Science Essential Content Standards and Expectations

NGSS Dimensions	MSS High School Practices of Science Literacy	Degree of Match
Scientific and Engineering Practices 1. Asking questions (for science) and defining problems (for engineering) 2. Developing and using models 3. Planning and carrying out investigations 4. Analyzing and interpreting data 5. Using mathematics and computational thinking 6. Constructing explanations (for science) and designing solutions (for engineering) 7. Engaging in argument from evidence 8. Obtaining, evaluating, and communicating information	Scientific Inquiry: 1. Generate new questions that can be investigated in the laboratory or field. 2. Critique aspects of scientific investigations. 3. Conduct scientific investigations using appropriate tools and techniques. 4. Identify patterns in data and relate patterns to theoretical models. 5. Describe a reason for a given conclusion using evidence from an investigation. 6. Explain how scientific evidence supports or refutes claims or explanations of phenomena. 7. Design and conduct a scientific investigation with a hypothesis, several control variables and one manipulated variable. Gather data and organize the results in graphs, tables and/or charts. Scientific Reflection and Social Implications: 1. Critique whether or not specific questions can be answered through scientific investigations. 2. Identify and critique arguments based on scientific evidence. 3. Use appropriate scientific knowledge in social arguments, recognizing their limitations. 4. Gather, synthesize, and evaluate information from multiple sources. 5. Discuss scientific topics in groups, make presentations, summarize what others have said, ask for clarification, take alternative perspectives, and defend a position. 6. Evaluate the future career and occupational prospects of science fields. 7. Explain why a claim or a conclusion is flawed. 8. Critique solutions to problems, given criteria and scientific constraints. 9. Identify scientific tradeoffs in design decisions and choose among alternative solutions. 10. Apply science principles or scientific data to anticipate effects of technological design decisions.	Low Match found between NGSS Scientific and Engineering Practices and MSS Practices of Science Literacy

Table A6. Crosswalk of the NGSS and MSS High School Science Essential Content Standards and Expectations (Continued)

NGSS: Crosscutting Concepts:	Key Practices of Science Literacy	Degree of Match
1. Patterns: Observed patterns of forms and events guide organization and classification, and they prompt questions about relationships and the factors that influence them. 2. Cause and effect: Mechanism and explanation. Events have causes, sometimes simple, sometimes multifaceted. A major activity of science is investigating and explaining causal relationships and the mechanisms by which they are mediated. Such mechanisms can then be tested across given contexts and used to predict and explain events in new contexts. 3. Scale, proportion, and quantity: In considering phenomena, it is critical to recognize what is relevant at different measures of size, time, and energy and to recognize how changes in scale, proportion, or quantity affect a system's structure or performance. 4. Systems and system models. Defining the system under study—specifying its boundaries and making explicit a model of that system—provides tools for understanding and testing ideas that are applicable throughout science and engineering. 5. Energy and matter: Flows, cycles, and conservation. Tracking fluxes of energy and matter into, out of, and within systems helps one understand the systems' possibilities and limitations. 6. Structure and function. The way in which an object or living thing is shaped and its substructure determine many of its properties and functions. 7. Stability and change. For natural and built systems alike, conditions of stability and determinants of rates of change or evolution of a system are critical elements of study.	Scientific Inquiry: 1. Generate new questions that can be investigated in the laboratory or field. 2. Critique aspects of scientific investigations. 3. Conduct scientific investigations using appropriate tools and techniques. 4. Identify patterns in data and relate patterns to theoretical models. 5. Describe a reason for a given conclusion using evidence from an investigation. 6. Explain how scientific evidence supports or refutes claims or explanations of phenomena. 7. Design and conduct a scientific investigation with a hypothesis, several control variables and one manipulated variable. Gather data and organize the results in graphs, tables and/or charts. Reflection and Social Implications: 1. Critique whether or not specific questions can be answered through scientific investigations. 2. Identify and critique arguments about personal or societal issues based on scientific evidence. 3. Use appropriate scientific knowledge in social arguments, recognizing their limitations. 4. Gather, synthesize, and evaluate information from multiple sources. 5. Discuss scientific topics in groups, make presentations summarize what others have said, ask for clarification, take alternative perspectives, and defend a position. 6. Evaluate why a claim or conclusion is flawed. 7. Critique solutions to problems, given criteria and scientific constraints. 8. Identify scientific tradeoffs in design decisions and choose among alternative solutions. 9. Apply science principles or scientific data to anticipate effects of technological design decisions.	Low Match found between NGSS Crosscutting Concepts and MSS Key Practices of Science Literacy

Table A6. Crosswalk of the NGSS and MSS High School Science Essential Content Standards and Expectations (Continued)

NGSS Disciplinary Core Ideas for High School	MSS Disciplines for High School	Degree of Match
High School Physical Sciences: Matter and its Interactions: • Structure and Properties of Matter • Chemical Reactions • Nuclear Processes • Structure and Properties of Matter Motion and stability: Forces and Interactions • Structure and Properties of Matter • Forces and Motion • Types of Interactions • Definitions of Energy (Electrical Energy) Energy • Definitions of Energy • Conservation of Energy and Energy Transfer • Relationship Between Energy and Forces • Energy in Chemical Processes Waves and their applications in technologies for information transfer • Energy in Chemical Processes • Wave Properties • Electromagnetic Radiation • Information Technologies and Instrumentation	Physics and Chemistry: Inquiry, Reflection and Social Implications Physics: Motion of Objects: • Position – Time: • Velocity – Time: Forces and Motion: • Basic Forces in Nature: • Net Forces • Newton's Third Law • Forces and Acceleration • Gravitational Interactions • Electrical Charges Forms of Energy and Energy Transformation: • Energy Transfer • Energy Transformation • Kinetic and Potential Energy • Wave Characteristics • Mechanical Wave Propagation • Electromagnetic Waves • Wave Behavior – Reflection and Refraction • Nature of Light • Current Electricity • Nuclear Reactions: Chemistry: Forms of Energy: • Molecules in Motion Energy Transfer and Conservation: • Heating Impacts • Endothermic and Exothermic Reactions: Properties of Matter: • Nomenclature • Properties of Substances • Atomic Structure: • Periodic Table • Neural Atoms, Ions and Isotopes Changes in Matter: • Chemical Changes • Phase Change/Diagrams • Chemical Bonds - Trends • Acids and Bases • Carbon Chemistry	Moderate Match found between NGSS Physical Sciences and MSS Physics and Chemistry for High School

Table A6. Crosswalk of the NGSS and MSS High School Science Essential Content Standards and Expectations (Continued)

High School Life Sciences From Molecules to Organisms: Structures and Processes • Structure and Function • Growth and Development of Organisms • Organization for Matter and Energy Flow Organisms Ecosystems: Interactions, Energy, and Dynamics • Interdependent Relationships in Ecosystems • Cycles of Matter and Energy Transfer in Ecosystems • Ecosystem Dynamics, Functioning, and Resilience • Social Interactions and Group Behavior • Biodiversity and Humans • Energy in Chemical Processes • Developing Possible Solutions Heredity: Inheritance and Variation of Traits • Structure and Function • Inheritance of Traits • Variation of Traits Biological Evolution: Unity and Diversity: • Evidence of Common Ancestry and Diversity • Natural Selection • Adaptation • Biodiversity and Humans	Biology: Scientific Inquiry, Reflection and Social Implications: Critique solutions to problems, given criteria and scientific constraints. Organization and Development of Living Systems: • Transformation of Matter and Energy in Cells • Organic Molecules • Proteins • Maintaining Environmental Stability • Cell Specialization • Living Organism Composition Interdependence of Living Systems and the Environment: • Photosynthesis and Respiration • Ecosystems • Element Recombination • Changes in Ecosystems • Populations Genetics: Genetics and Inherited Traits • Genetics and Inherited Traits • DNA • Cell Division – Mitosis and Meiosis Evolution and Biodiversity: • Theory of Evolution • Natural Selection	Moderate Match between NGSS Life Sciences and MSS Biology
High School Earth and Space Sciences: Earth's Place in the Universe: • The Universe and Its Stars • Earth and the Solar System • The History of Planet Earth Earth's Systems: • Earth Materials and Systems Plate Tectonics and Large-Scale System Interactions • The Roles of Water in Earth's Surface Processes • Weather and Climate • Biogeology Earth and Human Activity: • Natural Resources • Natural Hazards • Human Impacts on Earth Systems • Global Climate Change	Earth Science: Inquiry, Reflection and Social Implications Earth Systems: • Earth Systems Overview • Energy in Earth Systems • Biochemical Cycles • Resources and Human Impacts on Earth Systems Solid Earth: • Advance Rock Cycle • Interior of the Earth • Plate Tectonics • Earthquakes and Volcanoes Fluid Earth: • Hydrogeology • Oceans and Climate • Severe Weather Earth in Space and Time: • The Earth in Space • The Sun • Earth History and Geologic Time • Climate Change	Moderate Match between NGSS Earth and Space Sciences and MSS Earth Science

Table A6. Crosswalk of the NGSS and MSS High School Science Essential Content Standards and Expectations (Continued)

High School Engineering, Technology, and Applications of Science • Defining and Delimiting Engineering Problems: • Developing Possible Solutions • Optimizing the Design Solution	**Reflection and Social Implications:** 1. Critique whether or not specific questions can be answered through scientific investigations. 2. Identify and critique arguments about personal or societal issues based on scientific evidence. 3. Use appropriate scientific knowledge in social arguments, recognizing their limitations. 4. Gather, synthesize, and evaluate information from multiple sources. 5. Discuss scientific topics in groups, make presentations summarize what others have said, ask for clarification, take alternative perspectives, and defend a position. 6. Evaluate why a claim or conclusion is flawed. 7. Critique solutions to problems, given criteria and scientific constraints. 8. Identify scientific tradeoffs in design decisions and choose among alternative solutions. 9. Apply science principles or scientific data to anticipate effects of technological design decisions.	**Low Match between NGSS Engineering, Technology, and Applications of Science and MSS Reflection and Social Implications**
Overall Degree of Match		**Low to Moderate**

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