STATE OF MICHIGAN
DEPARTMENT OF EDUCATION
LANSING

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MICHAEL F. RICE, Ph.D.
STATE SUPERINTENDENT

MEMORANDUM

DATE: September 28, 2021

TO: State Board of Education

FROM: Michael F. Rice, Ph.D., Chairperson

SUBJECT: Presentation of the Proposed Standards for the Preparation of Middle Grades and High School Science Teachers

In pursuit of Michigan's Strategic Education Plan Guiding Principles that "all students have access to high quality instruction" and "all educators have the resources, support, and training needed to educate students," this proposal is presented to the State Board of Education (SBE) for the revision and adoption of new Standards for the Preparation of Middle Grades (5-9) and High School (7-12) Science Teachers. These standards would replace Michigan's current preparation standards for teachers in the areas of integrated science, biology, chemistry, earth and space science, physical science, and physics. This update would inform program development and continuous improvement efforts at Michigan's educator preparation institutions.

In November 2018 and August 2020, the SBE adopted new Standards for the Preparation of Teachers of Lower Elementary (grades PK-3) and Upper Elementary (grades 3-6) and Middle Grades (grades 5-9) and High School (grades 7-12) English Language Arts and Mathematics. Following development of these standards, stakeholder groups representing PK-12 science teachers, science curriculum and instruction experts, college and university teacher educators, and college and university science educators began meeting to revise Michigan's teacher preparation standards in science, which included standards for integrated science, biology, chemistry, earth and space science, and physics. Stakeholders included experts in adolescent learning and development and professional teacher preparation, and science instruction and content, including the above-named sub-disciplines of science. These groups met consistently from September 2019 through July 2021 to develop new sets of preparation standards in science for the Middle Grades (5-9) and High School (7-12) grade bands.

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Additionally, feedback was provided throughout the process from the Michigan Science Teachers Association, Michigan Mathematics and Science Learning Network, the Michigan Science Professional Learning Network, and the Confederation of Michigan Tribal Education Directors. Additional feedback was solicited from selected stakeholders representing PK-12 schools and districts, intermediate school districts, college and university teacher education programs, the education research community, and teacher and administrator professional organizations. All feedback was reviewed by the original stakeholder groups for refinement of the draft standards.

Attachment A presents an introduction to the standards, including the development of each set of standards, background, framework development, and stakeholders involved in the drafting and reviewing process. Attachment B provides the Standards for the Preparation of Middle Grades and High School Science Teachers. Attachment C provides the Middle Grades Standards for Optional Disciplinary Specializations. Attachment D provides the High School Standards for Optional Disciplinary Specializations. Attachment E describes the framework used to develop the proposed standards.

This presentation will be followed by a period of public comment and a request for approval at the February 2022 SBE meeting.

Introduction to Standards for the Preparation of Middle Grades (5-9) and High School (7-12) Science Teachers

Development of the Proposed Standards

Since 2015, the Michigan Department of Education (MDE), in collaboration with Michigan's stakeholders, has been working to revise Michigan's teacher certification structure and improve the preparation of the educator workforce in Michigan. This is in direct alignment with Michigan's Top 10 Strategic Education Plan.

This collaboration has led to the design of a structure that places students at the heart of the system. A key goal of this structure is deeper preparation of teachers to meet the unique learning, developmental, and social-emotional needs of children at each grade level. This structure includes focused grade bands to provide new teachers with specialized knowledge about the students and content they will teach and defined clinical experiences and foundational coursework for each grade band.

The purpose of the Standards for the Preparation of Middle Grades (5-9) and High School (7-12) Science Teachers is to establish a shared vision for the core knowledge, skills, and dispositions that well-prepared beginning science teachers of middle level and high school students in Michigan should possess and demonstrate in their teaching. The standards reflect a vision of a well-prepared beginning teacher who is prepared to enact high-quality science instruction; address the needs of the whole child; use relevant, research-based criteria to establish a supportive, engaging environment that fosters learning; and use practices that meet the individual adolescent's needs. These standards are intended to support the preparation of classroom educators who will have deep understanding of science content for teaching, enact best instructional practices, and be ethically guided and prepared to address the state standards for student science learning.

Building on the work of the certification restructuring and the revision and adoption of teacher preparation standards for the Early Elementary (PK-3) and Upper Elementary (3-6) grade bands, as well as English Language Arts, Mathematics, and Professional Knowledge and Skills for the Middle Grades (5-9) and High School (7-12) grade bands, a stakeholder committee was convened to develop preparation standards in science for the 5-9 and 7-12 grade bands. This group, representing PK-12 science teachers, science curriculum and instruction experts, college and university teacher educators, and college and university science educators began meeting to revise Michigan's teacher preparation standards in science, which included standards for integrated science, biology, chemistry, earth and space science, physical science, and physics. Stakeholders included experts in adolescent learning and development and professional teacher preparation, and science instruction and content, including the above-named sub-disciplines of science.

The stakeholder committee began its work by reviewing Michigan's current Standards for the Preparation of Teachers of Integrated Science–Secondary, adopted by the State Board of Education (SBE) in 2002, to determine whether they provided adequate guidance to prepare teachers to support students in the 5-9 and 7-12 grade bands in achieving the Michigan K-12 Science Standards. The committee considered whether to reaffirm existing Michigan teacher preparation standards, compose new standards, or adopt a national set of standards as Michigan's standards. They unanimously recommended that new science preparation standards be composed for two reasons: 1) to integrate science and engineering practices and crosscutting concepts with science knowledge, and 2) to align with both the National Science Teachers Association's (NSTA) Teacher Preparation Standards and Michigan's K-12 Science Standards. The following were used as source material and guidance:

- NSTA Teacher Preparation Standards and NSTA Middle School Content Analysis and NSTA Secondary Content Analysis
- MDE Core Teaching Practices
- MDE Clinical Experiences Requirements
- Upper Elementary (Grades 3-6) Teacher Preparation Standards for Science
- Michigan K-12 Science Standards
- A Vision for NSF Earth Sciences 2020-2030: Earth in Time
- Equity and Family Engagement
- MDE Focus on Whole Child
- MDE Strategic Plan Guiding Principles

At the start, the committee determined that because of the three-dimensional nature of the Michigan K-12 Science Standards, a similar framework would be required to guide the writing of the new preparation standards to ensure they align well with the K-12 standards. The stakeholders determined that this framework should both mirror the Michigan K-12 Science Standards' three-dimensional framework and allow for integration of and alignment with all of the key MDE initiatives and essential aspects identified by these source documents for science teacher preparation.

The three components of the framework stakeholders developed to draft these proposed standards are termed facets. The first facet, core knowledge, defines the knowledge needed to teach science, including both science content and knowledge of learners and learning, planning and instruction, and safety in science instruction. The second facet, science teaching practices, contains the skills and craft of science teaching and describes what well-prepared beginning teachers of science need to be able to do with the core knowledge to teach students. Finally, the third facet, guiding principles for teaching science, are intellectual tools and critical dispositions which serve as a mindful lens for decision-making in a variety of situations to promote science learning for all students. These three facets were then braided together to draft these proposed standards in such a way that each standard has an element of each facet. Further explanation of the stakeholders' rationale in developing a framework with three facets can be found in the Science Teacher Preparation Standards Framework in Attachment E.

The stakeholder committee met twice monthly beginning in September 2019 through July 2021. The framework was developed by January 2021, and the standards for all science endorsements drafted by June 2021. The committee solicited feedback from additional stakeholders with expertise in science content, instruction, and teacher preparation for middle grades and high school and met several times in July 2021 to refine the draft standards in response to this feedback and to ensure alignment between the standards and research on effective science instruction.

Resulting Shifts

These proposed standards represent several shifts from the current science teacher preparation standards:

1. *Multi-faceted* – The proposed standards shift to a clear focus on the multi-faceted understandings well-prepared beginning teachers need to teach science and include an essential balance between core knowledge aspects of pedagogy and content knowledge, direct alignment with K-12 science standards, and contextualized knowledge within principled practice.
2. *Equity* – The proposed standards have a deep focus on equity, shifting the vision of a well-prepared beginning teacher at the secondary level from an emphasis on possessing decontextualized content knowledge and toward an emphasis on classroom practices and contextualized understandings of science instruction that address the diverse social, emotional, developmental, and learning needs of the whole child.
3. *Performance-based* – The proposed standards are written in such a way as to enable the shift toward practice-based teacher preparation programs to ensure candidates have had multiple opportunities to practice the craft of teaching and strengthen it based on specific feedback about their enactment of science teaching practices.

Structure of the Endorsements

The stakeholders recommended that all teacher candidates pursuing certification with an endorsement to teach science earn a broad Science endorsement as their baseline credential. Candidates then have the option, either as part of initial preparation or as an additional endorsement, to stack an endorsement in a specialized science discipline onto the broad endorsement. As a result of this endorsement structure, these standards were intentionally developed in such a way that the broad Science endorsement contains all of the necessary knowledge and skills that a well-prepared beginning middle grades or high school science teacher needs to teach coursework addressing Michigan K-12 Science Standards for the respective grade band. This allows for the specialized disciplinary endorsements to tightly focus on additional content knowledge needed to teach that sub-discipline in areas that are beyond the Michigan K-12 Science Standards for that grade band. The proposed standards encompass the following areas:

Table 1: Science Endorsement Structure

	Middle Grades (5-9)	High School (7-12)
ALL Science Teachers will earn one of these.	Middle Grades Science Endorsement	High School Science Endorsement
Optional Disciplinary Specializations may be added.	• Biology • Earth and Space Science • Physical Science	• Biology • Chemistry • Earth and Space Science • Physics

Only teacher candidates earning or possessing a middle grades Science (5-9) endorsement may add a middle grades biology, earth and space science, or physical science specialized disciplinary endorsement.

Only teacher candidates earning or possessing a high school Science (7-12) endorsement may add a high school biology, chemistry, earth and space science, or physics specialized disciplinary endorsement.

Placement Considerations

A middle grades science teacher will be well-prepared to teach science courses targeting grades 5 and middle school level Michigan Science Standards.

A middle grades science teacher with an optional disciplinary specialized endorsement will be well-prepared to teach science courses targeting grades 5 and middle school level Michigan science standards and science courses **in that discipline at the introductory high school level**.

A high school science teacher will be well-prepared to teach science courses targeting high school level Michigan Science Standards.

A high school science teacher with an optional disciplinary specialized endorsement will be well-prepared to teach science courses targeting high school level Michigan Science Standards and science courses **in that discipline at the advanced high school level,** just beyond the Michigan Science Standards and Michigan Merit Curriculum.

Table 2: The following chart is intended to clarify the placement considerations:

Endorsement or Combination	This teacher is well-prepared to teach:
Middle Grades Science only	Courses with grades 5-9 students that target grade 5 or Middle School Michigan Science Standards.
Middle Grades Science + *MG Biology*	Courses with grades 5-9 students that target grade 5 or Middle School Michigan Science Standards AND courses that target beginning level life science standards in the High School Michigan Science Standards.
Middle Grades Science + *MG Earth and Space Science*	Courses with grades 5-9 students that target grade 5 or Middle School Michigan Science Standards AND courses that target beginning level earth and space standards in the High School Michigan Science Standards.
Middle Grades Science + *MG Physical Science*	Courses with grades 5-9 students that target grade 5 or Middle School Michigan Science Standards AND courses that target beginning level physical science standards in the High School Michigan Science Standards.
High School Science only	Courses with grades 7-12 students that target High School Michigan Science Standards.
High School Science + *HS Biology*	Courses with grades 7-12 students that target High School Michigan Science Standards AND courses that target advanced level life science standards beyond the High School Michigan Science Standards.

High School Science + *HS Chemistry*	Courses with grades 7-12 students that target High School Michigan Science Standards AND courses that target advanced level chemistry area physical science standards beyond the High School Michigan Science Standards.
High School Science + *HS Earth and Space Science*	Courses with grades 7-12 students that target High School Michigan Science Standards AND courses that target advanced level earth and space science standards beyond the High School Michigan Science Standards.
High School Science + *HS Physics*	Courses with grades 7-12 students that target High School Michigan Science Standards AND courses that target advanced level physics area physical science standards beyond the High School Michigan Science Standards.

Participants in Science Teacher Preparation Standards Development

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Standards for the Preparation of Middle Grades (5-9) and High School (7-12) Science Teachers

SBE PRESENTATION DRAFT

MIDDLE GRADES (MG) AND HIGH SCHOOL (HS) SCIENCE TEACHER PREPARATION STANDARDS

MG/HS.S1. LEARNERS AND LEARNING ENVIRONMENTS

Well-prepared beginning teachers of science:

S1.1 Learn about, consider, and incorporate students' backgrounds to plan and adapt instruction that leverages the iterative nature of sense-making and promotes positive student identities.

S1.2 Monitor and maintain relationships with students while engaging them in productive struggle and discourse to challenge science ideas and construct science meaning together, keeping in mind the importance of supporting each student's development through scaffolded sense-making.

S1.3 Encourage students to share their thinking about phenomena or problems with intentional use of talk moves in science to foster an inclusive, equitable and anti-bias environment that respects students' cultures.

S1.4 Ensure that group tasks and structures allow all students to build understanding, identities, and perceptions as science learners, in a variety of environments (e.g., the laboratory, field, and community) while respecting culturally different ways of knowing and reinforcing their rightful presence in science.

S1.5 Engage students in learning activities using science and engineering practices and crosscutting concepts to socially construct explanations of a phenomenon or solutions to a problem.

MG/HS.S2. CONTENT PEDAGOGY

Well-prepared beginning teachers of science:

S2.1 Elicit and interpret student ideas about anchoring scientific phenomena and problems in three-dimensional teaching and learning situations to make instructional decisions that engage students in collaborative, evidence-based sense-making, while valuing all students' ways of knowing and doing science.

S2.2 Design three-dimensional learning experiences to connect to and build upon the lives of learners by leveraging learners' prior experiences and knowledge, using varying research-based pedagogies such as talk and group work in ways that are culturally sustaining and enhance scientific ways of thinking.

S2.3 Uncover and consider students' verbal and visible thinking to plan and implement appropriate differentiation and research-based pedagogical strategies to support and prioritize student needs, perspectives, questions, and problems so that all students develop conceptual scientific knowledge.

S2.4 Support students to construct arguments to develop and defend explanations of scientific phenomena or solutions to engineering problems through the applications of appropriate scientific practices and crosscutting concepts so that students may be empowered to contribute to scientific problem solving in their community and in the world.

S2.5 Create opportunities for students to value diverse ways of thinking that build on their histories and experiences, while mobilizing social capital to engage all students in solving problems and using engineering practices.

S2.6 Build mutual trust with students through caring support and alignment of instruction and assessment strategies which address students' prior knowledge and partial understandings while navigating tensions between alternative and canonical ideas or ways of knowing.

S2.7 Select and integrate science-specific technological tools which engage learners in three-dimensional learning to explore, describe, and explain phenomena and support students' conceptual understanding.

S2.8 Uncover and consider students' thinking to select appropriate instructional strategies that illustrate the interdisciplinary nature of science and engineering and that allow students to demonstrate sense-making and understanding in different, valid, and informative ways.

S2.9 Support students to persevere in making sense of new observations, information, or data and to develop arguments supported by credible evidence and valid reasoning using connections to other core disciplines (mathematics, social studies, and English language arts).

MG/HS.S3. IMPACT ON LEARNING

Well-prepared beginning teachers of science:

S3.1 Give specific and timely verbal feedback to support student sense-making via formative assessment used to recognize and assess learners' ideas, life experiences and understanding while engaging students in high-level challenges that build toward citizenship, stewardship, and lifelong community engagement.

S3.2 Prepare constructive written feedback for students from assessments that are designed to show learning and application of three-dimensional understanding in order to move them toward productive sense-making situated within their lived experiences, building on existing ideas, assets, resources, and ways of knowing.

S3.3 Reflect on, interpret, and purposefully disaggregate summative assessment data to inform future planning and teaching, with particular attention to student demographics and learning progress, being thoughtful with regard to how assessment information is used, and the potential impact on students' identities as scientists.

MG/HS.S4. SAFETY

Well-prepared beginning teachers of science:

S4.1 Select and modify instructional materials and activities to apprentice students and build their agency in safety techniques for the purpose of exploring phenomena or solving problems using knowledge about procurement, preparation, use, storage, dispensing, supervision, and disposal of chemicals/materials/equipment.

S4.2 Establish shared ownership within the entire classroom community of roles, routines, and safety protocols to minimize hazardous situations, implement emergency procedures, maintain safety equipment, and follow policies and procedures that comply with established state and national guidelines and standards, and best professional practices while monitoring, coaching, and providing feedback to collaboratively create an environment that is physically safe.

S4.3 Plan intentionally for discourse around ethical and legal decision-making adhering strictly to science safety protocols with respect to safe and humane treatment of all living organisms including their collection, care and use in and out of the classroom, and creating an environment that is safe for students who have varying perspectives on the treatment of living organisms.

MG/HS.S5. PROFESSIONAL KNOWLEDGE AND SKILLS

Well-prepared beginning teachers of science:

S5.1 Use and reflect on assessment evidence of the three-dimensional aspects of student science understanding while honoring students' multiple ways of knowing, doing, and communicating their thinking to continually improve instructional effectiveness and professional growth that ensures a rightful presence in science for all students.

S5.2 Examine and manage professional growth while engaging in professional learning to remain current and open to learning from students and colleagues in order to deepen and grow in teaching knowledge, skills and dispositions, including the ability to employ science-specific technology and be culturally responsive.

MG/HS.S6. SPECIALIZED CONTENT KNOWLEDGE FOR ALL SCIENCE TEACHERS

Well-prepared beginning teachers of science:

S6.1 Use tools and strategies to ensure all students have equitable opportunities to understand the nature of science and the cultural norms and values inherent in the current and historical development of scientific knowledge, empowering students toward action that contributes to scientific problem solving in their community and in the world.

S6.2 As part of planning, unpack big ideas within a learning sequence in order to identify crosscutting concepts, disciplinary core ideas, science and engineering practices, and ensure the incorporation of science-specific technologies and contributions of diverse populations to science.

S6.3 Reflect and interpret student thinking and understanding while considering science standards, learning progressions, and sequencing of science content in order to scaffold and support student sense-making.

S6.4 Select and modify instructional materials that engage students in using grade appropriate elements of the disciplinary core ideas, science and engineering practices and crosscutting concepts to explore, describe, and explain phenomena or design solutions within a classroom environment where all students participate in the co-construction of knowledge.

S6.5 Engage students in sense-making cycles of activity to develop understanding of the major scientific concepts, principles, theories, laws, and interrelationships to explain phenomena and solve problems together as a classroom community of learners.

S6.5 Details for Middle Grades	S6.5 Details for High School
S6.5A LIFE SCIENCE FOR MIDDLE GRADES **LS1: From Molecules to Organisms: Structures and Processes** Well-prepared beginning teachers of science will engage in sense-making cycles of activity around key questions related to From Molecules to Organisms: Structures and Processes to explain phenomena and solve problems together as a classroom community of learners. **LS2: Ecosystems: Interactions, Energy, and Dynamics** Well-prepared beginning teachers of science will engage in sense-making cycles of activity around key questions related to Ecosystems: Interactions, Energy, and Dynamics to explain phenomena and solve problems together as a classroom community of learners. **LS3: Heredity: Inheritance and Variation of Traits** Well-prepared beginning teachers of science will engage in sense-making cycles of activity around key questions related to Heredity: Inheritance and Variation of Traits to explain phenomena and solve problems together as a classroom community of learners.	**S6.5A LIFE SCIENCE FOR HIGH SCHOOL** **LS1: From Molecules to Organisms: Structures and Processes** Well-prepared beginning teachers of science will engage in sense-making cycles of activity around key questions related to From Molecules to Organisms: Structures and Processes to explain phenomena and solve problems together as a classroom community of learners. **LS2: Ecosystems: Interactions, Energy, and Dynamics** Well-prepared beginning teachers of science will engage in sense-making cycles of activity around key questions related to Ecosystems: Interactions, Energy, and Dynamics to explain phenomena and solve problems together as a classroom community of learners. **LS3: Heredity: Inheritance and Variation of Traits** Well-prepared beginning teachers of science will engage in sense-making cycles of activity around key questions related to Heredity: Inheritance and Variation of Traits to explain phenomena and solve problems together as a classroom community of learners.

LS4: Biological Evolution: Unity and Diversity Well-prepared beginning teachers of science will engage in sense-making cycles of activity around key questions related to Biological Evolution: Unity and Diversity to explain phenomena and solve problems together as a classroom community of learners.	**LS4: Biological Evolution: Unity and Diversity** Well-prepared beginning teachers of science will engage in sense-making cycles of activity around key questions related to Biological Evolution: Unity and Diversity to explain phenomena and solve problems together as a classroom community of learners.
S6.5B EARTH AND SPACE SCIENCE FOR MIDDLE GRADES **ESS1: Earth's Place in the Universe** Well-prepared beginning teachers of science will engage in sense-making cycles of activity around key questions related to Earth's Place in the Universe to explain phenomena and solve problems together as a classroom community of learners. **ESS2: Earth's Systems** Well-prepared beginning teachers of science will engage in sense-making cycles of activity around key questions related to Earth's Systems to explain phenomena and solve problems together as a classroom community of learners. **ESS3: Earth and Human Activity** Well-prepared beginning teachers of science will engage in sense-making cycles of activity around key questions related to Earth and Human Activity to explain phenomena and solve problems together as a classroom community of learners.	**S6.5C EARTH AND SPACE SCIENCE FOR HIGH SCHOOL** **ESS1: Earth's Place in the Universe** Well-prepared beginning teachers of science will engage in sense-making cycles of activity around key questions related to Earth's Place in the Universe to explain phenomena and solve problems together as a classroom community of learners. **ESS2: Earth's Systems** Well-prepared beginning teachers of science will engage in sense-making cycles of activity around key questions related to Earth's Systems to explain phenomena and solve problems together as a classroom community of learners. **ESS3: Earth and Human Activity** Well-prepared beginning teachers of science will engage in sense-making cycles of activity around key questions related to Earth and Human Activity to explain phenomena and solve problems together as a classroom community of learners.
S6.5C PHYSICAL SCIENCE FOR MIDDLE GRADES **PS1: Matter and Its Interactions** Well-prepared beginning teachers of science will engage in sense-making cycles of activity around key questions related to Matter and Its Interactions to explain phenomena and solve problems together as a classroom community of learners.	**S6.5B CHEMISTRY FOR HIGH SCHOOL** **PS1: Matter and Its Interactions** Well-prepared beginning teachers of science will engage in sense-making cycles of activity around key questions related to Matter and Its Interactions to explain phenomena and solve problems together as a classroom community of learners.

PS2: Motion and Stability: Forces and Interactions
Well-prepared beginning teachers of science will engage in sense-making cycles of activity around key questions related to Motion and Stability: Forces and Interactions to explain phenomena and solve problems together as a classroom community of learners.

PS3: Energy
Well-prepared beginning teachers of science will engage in sense-making cycles of activity around key questions related to Energy to explain phenomena and solve problems together as a classroom community of learners.

PS4: Waves and Their Applications in Technologies for Information Transfer
Well-prepared beginning teachers of science will engage in sense-making cycles of activity around the Waves and Their Applications in Technologies for Information Transfer to explain phenomena and solve problems together as a classroom community of learners.

PS3:[1] Energy
Well-prepared beginning teachers of science will engage in sense-making cycles of activity around key questions related to Energy to explain phenomena and solve problems together as a classroom community of learners.

PS4: Waves and Their Applications in Technologies for Information Transfer
Well-prepared beginning teachers of science will engage in sense-making cycles of activity around key questions related to Waves and Their Applications in Technologies for Information Transfer to explain phenomena and solve problems together as a classroom community of learners.

PSO: Organic Chemistry
Well-prepared beginning teachers of science will engage in sense-making cycles of activity around key questions related to Organic Chemistry to explain phenomena and solve problems together as a classroom community of learners.

PSH: Human Impact on the Environment
Well-prepared beginning teachers of science will engage in sense-making cycles of activity around key questions related to Human Impact on the Environment to explain phenomena and solve problems together as a classroom community of learners.

S6.5D PHYSICS FOR HIGH SCHOOL
PS1: Matter and Its Interactions
Well-prepared beginning teachers of science will engage in sense-making cycles of activity around key questions related to Matter and its Interactions to explain phenomena and solve problems together as a classroom community of learners.

[1] PS2 concepts are not specifically called out in the high school chemistry but included in high school physics.

	PS2: Motion and Stability: Forces and Interactions Well-prepared beginning teachers of science will engage in sense-making cycles of activity around key questions related to Motion and Stability: Forces and Interactions to explain phenomena and solve problems together as a classroom community of learners. **PS3: Energy** Well-prepared beginning teachers of science will engage in sense-making cycles of activity around key questions related to Energy to explain phenomena and solve problems together as a classroom community of learners. **PS4: Waves and Their Applications in Technologies for Information Transfer** Well-prepared beginning teachers of science will engage in sense-making cycles of activity around key questions related to Waves and Their Applications in Technologies for Information Transfer to explain phenomena and solve problems together as a classroom community of learners.
S6.5D ENGINEERING FOR MIDDLE GRADES **ETS1: Engineering Design** Well-prepared beginning teachers of science will engage in problem solving through the design process and facilitate students to engage in the design process through engaging in the Engineering Design questions. **ETS2: Links Among Engineering, Technology, Science, and Society** Well-prepared beginning teachers of science will engage in problem solving through the design process and facilitate students to engage in the design process through engaging in the Links Among Engineering, Technology, Science, and Society questions.	**S6.5E ENGINEERING FOR HIGH SCHOOL** **ETS1: Engineering Design** Well-prepared beginning teachers of science will engage in problem solving through the design process and facilitate students to engage in the design process through engaging in the Engineering Design questions. **ETS2: Links Among Engineering, Technology, Science, and Society** Well-prepared beginning teachers of science will engage in problem solving through the design process and facilitate students to engage in the design process through engaging in the Links Among Engineering, Technology, Science, and Society questions.

Standards for the Preparation of Middle Grades (5-9) Science Teachers in Optional Disciplinary Specializations

SBE PRESENTATION DRAFT

OPTIONAL DISCIPLINARY SPECIALIZATION IN BIOLOGY FOR GRADES 5-9 SCIENCE TEACHERS

MG.B.LS1.A: STRUCTURE AND FUNCTION: *How do the structures of organisms enable life's functions?*

1. What role do specialized cells play in living organisms?
2. How does the difference in structure between unicellular and multicellular organisms contribute to their function?
3. How does the development of cell theory demonstrate the nature of science?
4. What are the elements of a system that determine an individual's traits and how could we model that system?
5. What evidence supports the argument that changes in protein structure alter functioning of the cell?
6. How can the relationships among the hierarchical system of cells, tissues, organs, and systems be modeled?
7. How do we use scientific technologies to generate evidence about structures at the microscopic scale?
8. How does the polarity of the water molecule enable the function of living systems?
9. What evidence supports our understanding of the molecular composition of cells and their components?

MG.B.LS1.B: GROWTH AND DEVELOPMENT OF ORGANISMS: *How do organisms grow and develop?*

1. How can we model the relationships between mitosis, gene expression, and differentiation to explain the growth and development of multicellular organisms?
2. What argument can be constructed for why meiosis is essential for sexual reproduction?
3. How can the similarities and differences between mitosis and meiosis be modeled?

MG.B.LS1.C: ORGANIZATION FOR MATTER AND ENERGY FLOW IN ORGANISMS: *How do organisms obtain and use the matter and energy they need to live and grow?*

1. How can the growth of organisms be explained by drawing upon mechanisms for building complex organic molecules from simple elements?
2. How can we model the interactions between the light and dark reactions to demonstrate the transformations of matter and energy that occur during photosynthesis?
3. How do enzymes affect energy use in the breakdown and synthesis of molecules?

MG.B.LS1.D: INFORMATION PROCESSING: *How do organisms detect, process, and use information about the environment?*

1. How might functions associated with each of the main regions of the brain impact behavior?
2. What patterns distinguish reflexes from complex behaviors?
3. How is homeostasis maintained through feedback mechanisms?

MG.B.LS2.A: INTERDEPENDENT RELATIONSHIPS IN ECOSYSTEMS: *How do organisms interact with the living and nonliving environments to obtain matter and energy?*

1. How do interspecific interactions influence how organisms obtain matter and energy for survival and reproduction?
2. What evidence would support the claim that complex interactions within an ecosystem help to maintain relatively stable numbers and types of organisms in that ecosystem?

MG.B.LS2.B: CYCLES OF MATTER AND ENERGY TRANSFER IN ECOSYSTEMS: *How do matter and energy move through an ecosystem?*

1. What models demonstrate how matter and energy move <u>through and within</u> an ecosystem?
2. What models best illustrate the roles of photosynthesis and respiration in the movement of carbon through food chains and the cycling of carbon within ecosystems?
3. How can mathematical modeling be used to depict how the efficiency of energy flow through ecosystems impacts the number of organisms at increasingly higher trophic levels?
4. What data could be used to provide evidence that an imbalance in the global carbon cycle is leading to climate change?

MG.B.LS2.C: ECOSYSTEM DYNAMICS, FUNCTIONING, AND RESILIENCE: *What happens to ecosystems when the environment changes?*

1. How can we use models to predict the impact of a disruption to a physical or biological component of an ecosystem on the populations and communities within the ecosystem?
2. What data can we use to evaluate the anthropogenic changes that have occurred in the environment and their impacts on ecosystems?

MG.B.LS2.D: SOCIAL INTERACTIONS AND GROUP BEHAVIOR: *How do organisms interact in groups so as to benefit individuals?*

1. What evidence can be used to evaluate the role of group behavior on individual and species' chances to survive and reproduce?

MG.B.LS3.A: INHERITANCE OF TRAITS: *How are the characteristics of one generation related to the previous generation?*

1. What evidence can be used to support the claim that gene mutations result in changes in an organism?
2. What evidence was used to develop the structural model of DNA and how does this demonstrate the nature of science and historical ways that women and minorities have been challenged in their role in science?
3. How do DNA sequences lend themselves to regulatory functions?

MG.B.LS3.B: VARIATION OF TRAITS: *Why do individuals of the same species vary in how they look, function, and behave?*

1. What are the relationships among alleles and DNA, nucleotide sequences, protein synthesis, genes, and chromosomes?
2. How can you develop a model that demonstrates both the conservative nature of DNA replication and how it contributes to variation?
3. What are the mechanisms (including potential for mutation caused by environmental factors) involved in sexual and asexual reproduction that lead to the patterns of similarity and difference in how they each generate genetic variability?
4. How do both genetic and environmental factors affect expression/regulation of DNA to generate particular traits?
5. Why is genetic variability important?
6. How does the calculation of the probability of traits in future generations based on parental genotypes support making predictions about a population over time?

MG.B.LS4.A: EVIDENCE OF COMMON ANCESTRY AND DIVERSITY*: What evidence shows that different species are related?*

1. What forms of evidence are used to infer evolutionary relationships?
2. How do patterns in the fossil record document the existence, diversity, extinction, and change of life forms throughout the history of life on Earth?
3. How can the patterns inherent in a set of comparative DNA sequences be used to model evolutionary relationships?

MG.B.LS4.B: NATURAL SELECTION: *How does genetic variation among organisms affect survival and reproduction?*

1. How and through what technologies have humans influenced the inheritance of desired traits in organisms throughout history?
2. How can there be so many similarities among organisms yet so many different kinds of plants, animals, and microorganisms?
3. How are shifts in the numerical distribution of traits used as evidence to support that advantageous heritable traits tend to increase in a population?
4. How are natural selection, adaptations, and evolution interrelated?
5. Explain how various scientists contributed to the development of the theories of evolution by natural selection?

MG.B.LS4.C: ADAPTATION: *How does the environment influence populations of organisms over multiple generations?*

1. What is the potential impact of a new pathogen on a population?
2. How has the increase in prescribing antibiotics impacted the evolution of bacteria (including virulence and resistance)?

MG.B.LS4.D: BIODIVERSITY AND HUMANS: *What is biodiversity, how do humans affect it, and how does it affect humans?*

1. In what ways can changes in environmental conditions affect the distribution of species and/or habitats?
2. How can modeling predict and test the impacts of proposed solutions for protection of a threatened or endangered species?

Optional Disciplinary Specialization in Earth and Space Science Standards for Grades 5-9 Science Teachers

ESS1: EARTH'S PLACE IN THE UNIVERSE: What is the universe, and what is Earth's place in it?

MG.E.ESS1.A: THE UNIVERSE AND ITS STARS: *What is the Universe and what goes on in stars?*
1. What nuclear reactions take place that result in the Sun radiating energy?
2. How will the nuclear reactions in the Sun change over time?
3. What do the spectral patterns of distant stars reveal about their age and history?
4. How do the spectra of stars and galaxies provide evidence of their chemical composition?
5. What is the relationship between velocity and relative distance from Earth for these spectra?
6. How does a star's mass influence its evolution?

MG.E.ESS1.B: EARTH AND THE SOLAR SYSTEM: *What are the predictable patterns caused by Earth's motion in the Solar System?*
1. How can the mathematical representations of Kepler's Laws provide predictions of natural and man-made objects in the solar system?
2. What is the nature and period of oscillations in Earth's motions?
3. What positive and negative feedback can be seen in these oscillations?

MG.E.ESS1.C: HISTORY OF PLANET EARTH: *How do people reconstruct and date events in Earth's planetary history?*
1. In what ways can the decay of radioactive isotopes be used to establish an absolute age for Earth materials?
2. How do tectonic processes affect current patterns of continental and ocean floor features?
3. How do scientists use the mineralogic and chemical compositions of Earth and solar system materials to understand the conditions of Earth's earliest history?
4. How does the record of impacts and collisions provide information on the history of the Solar System?
5. How can a model be used as evidence to illustrate how Earth's internal and surface processes operate at different spatial and temporal scales to form continental and ocean-floor features?

ESS2: EARTH'S SYSTEMS: How and why is Earth constantly changing?

MG.E.ESS2.A: EARTH MATERIALS AND SYSTEMS: *How do Earth's major systems interact?*
1. In what ways can Earth's dynamic systems be modeled, over both short and long time spans?
2. How does Earth's internal energy drive small- and large-scale crustal processes?
3. How is the rate of change in Earth System processes interrelated?
4. How can seismic wave data indicate differences in density in the crust and mantle of the Earth?

5. What causes motion in the Earth's mantle?
6. How can the sequence of rocks in a given area provide evidence of the plate tectonic environment of their formation?
7. What experimental evidence can be used to identify different types of soil?
8. How can a quantitative model be used to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere?

MG.E.ESS2.B: PLATE TECTONICS AND LARGE-SCALE SYSTEM INTERACTIONS: *Why do the continents move, and what causes earthquakes and volcanoes?*

1. What are the sources of energy that drive Earth's surface and subsurface processes?

MG.E.ESS2.C: THE ROLES OF WATER IN EARTH'S SURFACE PROCESSES: *How do the properties and movements of water shape Earth's surface and affect its systems?*

1. How does the storage and movement of water, including but not limited to the properties of watersheds, mediate and facilitate short- and long-term processes on the surface and in the subsurface of the Earth?

MG.E.ESS2.D: WEATHER AND CLIMATE: *What regulates weather and climate?*

1. What energy transformations occur to incoming solar radiation as it is transferred between Earth systems?
2. What is the evidence in the rock and sediment record for changes in climate?
3. What are drivers for climate change?
4. Based on current rates of change in energy levels, what are some valid extrapolations for changes in climate and the impact on the biosphere, hydrosphere, and lithosphere?
5. What causes El Nino and La Nina events and what effect do these events have on weather, climate, and the environment?
6. How can models be used to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate?

MG.E.ESS2.E: BIOGEOLOGY: *How do living organisms alter Earth's processes and structures?*

1. How can organisms impact Earth's major systems?
2. How would the Earth's lithosphere, atmosphere, and hydrosphere be different in the absence of life?

ESS3: EARTH AND HUMAN ACTIVITY: *How do Earth's surface processes and human activities affect each other?*

MG.E.ESS3.A: NATURAL RESOURCES: *How do humans depend on Earth's resources?*

1. How are the Earth's resources unevenly distributed across the planet and what caused that distribution?
2. How has technology been employed to develop and promote the use of renewable energy resources?

MG.E.ESS3.B: NATURAL HAZARDS: *How do natural hazards affect individuals and societies?*

1. How have occurrences of natural hazards in local and regional and global environments driven human movements and populations in those environments?

MG.E.ESS3.C: HUMAN IMPACTS ON EARTH SYSTEMS: *How do humans change the planet?*

1. What changes in human behavior and technology can mitigate the negative impacts humans have had on Earth systems, including mining, urbanization, and atmospheric, aquatic, and terrestrial pollution?
2. How do different resource management approaches impact the long-term availability/sustainability of natural resources?

MG.E.ESS3.D: GLOBAL CLIMATE CHANGE: *How do people model and predict the effects of human activities on Earth's climate?*

1. What technological resources are available to advance Earth's positive feedback systems and mitigate negative feedback systems due to the use of resources by humans?

Optional Disciplinary Specialization in Physical Science Standards for Grades 5-9 Science Teachers

Chemistry

MG.P.PS1.A: MATTER AND ITS INTERACTIONS: *How can one explain the structure, properties, and interactions of matter?*

1. How does the analysis of data from investigations help determine the nature of matter?
2. How can the creation of models from data represent the nature of matter and the properties of its various states of matter?
3. What are chemical and physical properties and how are they used to identify substances?
4. How can data be used to model the relationships among the number of moles, volume, temperature, and pressure of gases?
5. What data supports the current model of an atom's structure?
6. What atomic models are/were commonly used and how were they developed over time?
7. What observations illustrate the limitations of the Bohr model of the atom?
8. How are patterns in atomic spectra related to our understanding of atomic structure?
9. How was the Periodic Table developed and what does that process show about the nature of science?
10. What patterns found in the Periodic Table predict structure, chemical properties, and physical properties of matter?
11. In what ways do atoms combine to form novel substances?
12. How is the stability of a molecule related to its energy?
13. What patterns exist in the characteristics of different types of bonding and how can these be predicted using the Periodic Table?
14. How can bonding characteristics be used to determine the shape of a molecule?
15. How can a molecule's structure be used to determine the polarity of a molecule?
16. What patterns in structure and bonding are used for naming chemical compounds and writing formulas?

MG.P.PS1.B: CHEMICAL REACTIONS: *How do substances combine or change (react) to make new substances? How does one characterize and explain these reactions and make predictions about them?*

1. What data supports the kinetic molecular theory explanation of chemical processes?
2. How is energy involved in a chemical reaction?
3. How can data from an investigation explain that a balanced chemical equation represents conservation of mass in a given chemical reaction?
4. How can the products and yield of a chemical reaction be predicted given the quantities of reactants?
5. How are observations of chemical reactions used to develop the activity series and predict the nature of chemical reactions?
6. How can the structure of electrochemical cells be described by chemical half reactions?

7. What patterns can be used to predict the resulting reaction given the strength of an acid and base?
8. How can an investigation be designed to show the change of pH during a titration?
9. In what ways can the rate of a chemical reaction be changed?
10. A change in what factors can shift a system at equilibrium?
11. In what ways are chemical processes used in the mining of metals, minerals, ores, and elements?
12. How are chemical processes used in biological phenomena?

MG.P.PS1.C: NUCLEAR PROCESSES: *What forces hold nuclei together and mediate nuclear processes?*
1. How do the amounts of subatomic particles change during nuclear decay?
2. How does the amount of radioactive materials change over the course of a nuclear decay reaction?
3. How can half-life be used to mathematically determine the age of rocks and other natural materials?

MG.P.PS3.A:[2] DEFINITIONS OF ENERGY: *What is energy?*
1. How can the change of energy during a phase change of a material be represented in a model?
2. How can the change in enthalpy be calculated during a chemical reaction?
3. How can the spontaneity of a reaction be explained based on the relationship between enthalpy, entropy, and free energy?
4. How can an investigation show how electrical energy is produced in a voltaic cell?
5. How can electrolysis be explained?
6. What evidence is there for the wave particle duality of electrons?

MG.P.PS3.B: CONSERVATION OF ENERGY AND ENERGY TRANSFER: *What is meant by conservation of energy?*
How is energy transferred between objects or systems?
1. How can the relationship between energy of a system and energy of its surroundings be used to determine the heat of a reaction?

MG.P.PS4.B: ELECTROMAGNETIC RADIATION: *What is light? How can one explain the varied effects that involve light? What other forms of electromagnetic radiation are there?*
1. How do quantum mechanical models and molecular orbital theory improve our ability to explain chemical behavior?

MG.P.PSO: ORGANIC CHEMISTRY: *What is Organic Chemistry? Why is carbon used in organic molecules?*
1. How do models explain how the atoms from glucose molecules combine with other elements to form more complex organic molecules?
2. What is the effect of the use of enzymes during the synthesis or breaking down of molecules?

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[2] PS2 concepts are included in the physics category of physical science

3. What are the different ways in which carbon atoms combine to make different classes of organic compounds?
4. How do different functional groups predict the properties and reactivity of organic compounds?
5. How does the structure of reactants in an organic reaction predict the products?

MG.P.PSH: HUMAN IMPACT ON THE ENVIRONMENT: *What impact have humans caused the environment? What evidence and data can be used to show the impact? What can humans do to have a positive impact on the environment?*
1. What is the greenhouse effect and how do greenhouse gases contribute to climate change?
2. How can chemistry design solutions to mitigate global climate change?
3. How can chemistry be used to investigate ways to mitigate other air quality concerns and design solutions?

Physics

MG.P.PS1.C: NUCLEAR PROCESSES: *What forces hold nuclei together and mediate nuclear processes?*
1. How is half-life used to determine the age of rocks and other natural materials?

MG.P.PS2.A: FORCES AND MOTION: *How can one predict an object's continued motion, changes in motion, or stability?*
1. How can an object's continued motion, changes in motion, or stability be predicted?
2. How can models be used to explain relationships among mass, velocity, acceleration, force, and momentum for macroscopic objects?
3. How can models help explain the nature of different forces?
4. What are the conceptual and mathematical relationships among velocity and mass for a collection of interacting objects, as in a collision?
5. How can a conceptual model be used to describe the size of collision forces?

MG.P.PS2B: TYPES OF INTERACTIONS: *What underlying forces explain the variety of interactions observed?*
1. What is the relationship between electric and magnetic fields, and electric and magnetic forces?

MG.P.PS2.C: STABILITY AND INSTABILITY IN PHYSICAL SYSTEMS: *Why are some physical systems more stable than others?*
1. How do you design an investigation to explore why some systems are more stable than others?
2. How do feedback mechanisms maintain stability in closed systems?
3. How is the Second Law of Thermodynamics and energy transfer principles applied to two components in an isolated system?

MG.P.PS3.A: DEFINITIONS OF ENERGY: *What is energy?*
1. What is energy and how is it measured?
2. What demonstrations can be done to demonstrate the presence of different forms of energy?
3. How can mathematics be used to describe energy transfer between objects?

4. How can systems be designed to harness energy to solve practical problems?

MG.P.PS3.B: CONSERVATION OF ENERGY AND ENERGY TRANSFER: *What is meant by conservation of energy? How is energy transferred between objects or systems?*
1. How does the system change when energy (electrical, thermal, and mechanical) flows in and out of it?
2. How can energy conservation be used to generate mathematical expressions to predict the behavior of a system?
3. How can electrical circuits be used to demonstrate energy transfer and transformation?

MG.P.PS3.C: RELATIONSHIP BETWEEN ENERGY AND FORCES: *How are forces related to energy?*
1. What are the conceptual and mathematical relationships between two objects interacting through electrical or gravitational fields?
2. How does calculus help provide insight into the connections between force and energy?
3. What are the conceptual and mathematical relationships among conservation of mass, momentum, energy, and charge as applied to systems of objects?

MG.P.PS3.D: ENERGY IN CHEMICAL PROCESSES AND EVERYDAY LIFE: *How do food and fuel provide energy? If energy is conserved, why do people say it is produced or used?*
1. How does Earth receive seemingly unlimited energy?
2. What are some real-world examples of applications of energy conversion?

MG.P.PS4.A: WAVE PROPERTIES: *What are the characteristic properties and behaviors of waves?*
1. What happens to light when it interacts with different materials?
2. How can information be digitized and communicated using the electromagnetic spectrum?
3. What is resonance and how is the concept applied to everyday events?

MG.P.PS4.B: ELECTROMAGNETIC RADIATION: *What is light? How can one explain the varied effects that involve light? What other forms of electromagnetic radiation are there?*
1. What forms of electromagnetic radiation exist?
2. What are the different models for electromagnetic radiation?
3. What are some practical applications of electromagnetic radiation?
4. How does electromagnetic radiation affect matter?
5. How does electromagnetic radiation influence the emission of energy by an atom?

Standards for the Preparation of High School (7-12) Science Teachers in Optional Disciplinary Specializations

SBE PRESENTATION DRAFT

Optional Disciplinary Specialization in Biology for Grades 7-12 Science Teachers

HS.B.LS1.A: STRUCTURE AND FUNCTION: *How do the structures of organisms enable life's functions?*

1. What is the role of energy in the making and breaking of polymers?
2. How might a change in the subunits of a polymer lead to changes in structure or function of the macromolecule?
3. What evidence supports the theory about the origin of eukaryotic cells?
4. How do the mechanisms for transport across membranes support energy conservation?
5. How are living systems affected by the presence or absence of subcellular components?
6. How are mathematical models used to help explain the ways in which osmoregularity mechanisms contribute to the health and survival of organisms?
7. How can we use scientific technologies to explore molecular sequences that provide insight into the evolutionary relationships between cells and molecules in various organisms?

HS.B.LS1.B: GROWTH AND DEVELOPMENT OF ORGANISMS: *How do organisms grow and develop?*

1. How does the cell cycle aid in the conservation of genetic information?
2. How do disruptions to the cell cycle impact a cell or organism?
3. How does the regulation of gene expression connect with phenotypic differences in cells and organisms?

HS.B.LS1.C: ORGANIZATION FOR MATTER AND ENERGY FLOW IN ORGANISMS: *How do organisms obtain and use the matter and energy they need to live and grow?*

1. How do organisms use energy or conserve energy to respond to environmental stimuli?
2. How might changes to the structure of an enzyme affect its function?
3. How does the cellular environment affect enzyme activity?
4. How is variation in the number and types of molecules within cells connected to the ability of the organism to survive and/or reproduce in different environments?
5. How can rates of transpiration be calculated or investigated?
6. How can rates of enzymatic reactions be investigated?

HS.B.LS1.D: INFORMATION PROCESSING: *How do organisms detect, process, and use information about the environment?*

1. What are the molecular bases of signaling mechanisms in cells?
2. How does communication in organisms get explained at varied scales - molecular, cellular, systems, organisms, ecosystems?

HS.B.LS2.A: INTERDEPENDENT RELATIONSHIPS IN ECOSYSTEMS: *How do organisms interact with the living and nonliving environments to obtain matter and energy?*

1. How can mathematical models help to predict or understand population growth?

2. How do density-dependent and density-independent factors interact to determine population growth curves?
3. How do we quantify community diversity? How are measures of community diversity used to evaluate and monitor the quality of ecosystems?

HS.B.LS2.B: CYCLES OF MATTER AND ENERGY TRANSFER IN ECOSYSTEMS: *How do matter and energy move through an ecosystem?*
1. How can differences in energy availability lead to different reproductive strategies related to tradeoffs between number of offspring and resource allocation per offspring?
2. What is the relationship between metabolic rate per unit body mass and the size of multicellular organisms?

HS.B.LS2.C: ECOSYSTEM DYNAMICS, FUNCTIONING, AND RESILIENCE: *What happens to ecosystems when the environment changes?*
1. How do interspecific interactions result in keystone species having effects on ecosystems that are disproportionate to their abundance?
2. How do geological and climatological patterns affect habitat change and ecosystem distribution?
3. How do biogeographical studies illustrate changes in habitat and ecosystem distribution over time?

HS.B.LS2.D: SOCIAL INTERACTIONS AND GROUP BEHAVIOR: *How do organisms interact in groups so as to benefit individuals?*
1. How are behavioral and/or physiological responses of organisms related to changes in the internal or external environment?
2. How do the behavioral responses of organisms affect their overall fitness and contribute to the success of the population?
3. How can cooperation or coordination between organisms, populations, and species result in enhanced movement of, or access to, matter and energy?
4. What behaviors can be investigated and modeled using model organisms such as Fruit Flies?

HS.B.LS3.A: INHERITANCE OF TRAITS: *How are the characteristics of one generation related to the previous generation?*
1. What role does the structure of nucleic acids play in how living systems transmit information?
2. How does our knowledge of shared, conserved, fundamental processes in genetics provide evidence for common ancestry?
3. How and what types of interactions regulate gene expression?
4. How do alterations in DNA sequences contribute to variation that can be subject to natural selection?(evolution?)
5. How are genetic engineering techniques used in analyzing or manipulating DNA?

HS.B.LS3.B: VARIATION OF TRAITS: *Why do individuals of the same species vary in how they look, function, and behave?*
1. How does the diversity of a species affect inheritance?

2. How does chromosomal inheritance generate genetic variation in sexual reproduction?
3. How is a species' genetic information diversified from generation to generation?

HS.B.LS4.A: EVIDENCE OF COMMON ANCESTRY AND DIVERSITY: *What evidence shows that different species are related?*
1. What conditions or changes in conditions cause a population to be more or less likely to evolve?
2. What and how are data, evidence and models used to provide evidence of the theory of evolution?
3. What patterns in species interaction encourage or slow changes in species?
4. What and how do mechanisms lead to changes in allele and genotype frequencies in populations?

HS.B.LS4.B: NATURAL SELECTION: *How does genetic variation among organisms affect survival and reproduction?*
1. How can evidence demonstrate that the environment influences populations of organisms over multiple generations?
2. What model(s) demonstrate that environmental changes impact the distribution of traits in a population?
3. How can reproductive isolation lead to speciation?
4. What evidence would support that natural selection has occurred in a population?
5. How can mathematical modeling be used to describe how natural selection may lead to increases and decreases of specific traits in populations over time?
6. What is meant by virulence and resistance?
7. What is the potential impact of a new pathogen on a population?
8. How does reproductive success determine evolutionary fitness?
9. How are changing biotic and abiotic environments predictive of impact on the rate and direction of evolution?

HS.B.LS4.C: ADAPTATION: *How does the environment influence populations of organisms over multiple generations?*
1. How does the process of gradual speciation influence the rate of evolutionary processes?
2. How does punctuated equilibrium influence evolutionary processes?
3. What type of conditions lead to rapid speciation events?
4. How is evolutionary change impacted by continuous variation across geographic ranges?

HS.B.LS4.D: BIODIVERSITY AND HUMANS: *What is biodiversity, how do humans affect it, and how does it affect humans?*
1. How can an ecosystem model be used to demonstrate the role of biodiversity?
2. How do changes in biodiversity affect humans?
3. How have humans impacted biodiversity?
4. How does human impact on biodiversity affect environmental, economic, and social considerations of the community?

5. In what ways can changes in environmental conditions (e.g., drought, deforestation, flood) and the rate of change of the environment affect the distribution or disappearance of traits in a species?
6. How can modeling predict and test the impacts of proposed solutions for protection of a threatened or endangered species?
7. How and what type of models can be used to measure human impact on biodiversity?
8. How can variations in the allele frequencies of a gene be used to provide evidence of speciation?

Optional Disciplinary Specialization in Chemistry for Grades 7-12 Science Teachers

HS.C.PS1.A: STRUCTURE AND PROPERTIES OF MATTER: *How do particles combine to form the variety of matter one observes?*

1. How does the ionization energy of atoms across periods in the Periodic Table account for the electron structure of atoms?
2. How does the electron configuration of an atom determine its photoelectric spectrum?
3. In what ways can the mass spectrum be used to identify and calculate the abundance of an isotope?
4. How do electron structures which are exceptions to the Octet rule affect the modeling of those structures?
5. What factors affect the bond length and bond polarity of covalent bonds?
6. How can the use of Lewis diagrams and VSEPR theory predict the structure and geometry of covalently bonded molecules and polyatomic ions?
7. How do molecular geometry and bonding affect the structural and electronic properties of molecules?
8. In what ways can Lewis diagrams and formal charges predict resonance structures?
9. What evidence supports the current model of the changes which occur during the formation of hybrid orbitals?
10. How does the ideal gas law describe the relationship between the macroscopic properties of a gas or mixture of gases?
11. How can a particulate model and graphical representations illustrate the relationship between the motion of particles and the macroscopic properties of gases?
12. How do interparticle forces and gas volumes influence non-ideal behavior of gases?
13. How can intermolecular interactions between particles be used to predict the solubility of ionic and molecular compounds in aqueous and nonaqueous solvents?

HS.C.PS1.B: CHEMICAL REACTIONS: *How do substances combine or change (react) to make new substances? How does one characterize and explain these reactions and make predictions about them?*

1. What patterns distinguish polyprotic acids from monoprotic acids?
2. What tests will differentiate acids and bases from other substances?
3. How can a reaction be identified as acid-base, oxidation-reduction, or precipitation using experimental data and observations?

4. What information is needed to determine a net-ionic equation from a given chemical reaction?
5. What structural characteristics and chemical properties characterize Lewis, Arrhenius, and Brønsted-Lowry acids and bases?
6. What patterns exist between Brønsted-Lowry acids, bases, their respective conjugate acid-base pairs?
7. How does pH change over the course of a titration?
8. What evidence indicates the chemical species present at any point during a titration?
9. What data is needed to determine the rate equation for a reaction?
10. How can a rate law be determined from a reaction mechanism?
11. Why is half-life a critical parameter for first-order reactions?
12. How can half reactions be used to balance redox reaction equations?
13. What experimental data or observations are necessary to represent and calculate the equilibrium constants, Kc or Kp?
14. What does the magnitude of K indicate about the relative concentrations of chemical species at equilibrium?
15. What is the relationship between Q, K, and the direction in which a reversible reaction will proceed to reach equilibrium?
16. How does Le Châterlier's principle and equilibrium law explain equilibrium shifts and changes in concentration of chemical species in a system at equilibrium?
17. What is the effect of a change in pH on the solubility of a salt?
18. How can the solubility of a salt be calculated based on the value of Ksp of the salt?
19. How does the relationship between the Gibbs free energy of a system and the equilibrium constant for the reaction predict the equilibrium position of the system?
20. How does the structure of water explain the amphoteric properties of water?
21. How can the values of pH, pOH be calculated for salts, strong acids and bases and weak acids and bases?
22. What is the relationship between pH, pOH, and Kw?
23. What data is needed to calculate the concentrations of major species in a solution, pH, and Ka or Kb of a monoprotic weak acid or weak base?
24. How can acid-base equilibrium concentrations be determined for weak acids and weak bases?
25. How do graphical representations of titrations of strong acids and strong bases differ from those of weak acids and weak bases?
26. What are the components and characteristics of buffer solutions?

HS.C.PS1.C: NUCLEAR PROCESSES: *What forces hold nuclei together and mediate nuclear processes?*

1. How does the structure of an isotope's nucleus affect the stability of the nucleus and type of radioactive decay observed by unstable nuclei?
2. What are the properties and uses of the energy and particles emitted from a radioisotope during nuclear decay?

HS.C.PS3.A:[3] DEFINITIONS OF ENERGY: *What is energy?*

[3] PS2 concepts are included in the physics optional disciplinary specialization

1. How does a graph of enthalpy of a system change during exothermic and endothermic processes?
2. What data is needed to calculate the change in entropy of a chemical or physical change?
3. What does the sign and magnitude of change in enthalpy, entropy, or free energy indicate about a chemical or physical process?
4. How can the spontaneity of a reaction be predicted using enthalpy, entropy, and free energy?
5. What factors cause a thermodynamically favored reaction to not occur at a measurable rate?
6. What can be done to drive a thermodynamically unfavorable electrochemical process?
7. How do changes in temperature, along with K, affect the extent to which a process is thermodynamically favored?
8. How does the relationship between n, ΔG^o, and E^o determine the extent to which a process is thermodynamically favored?
9. How can the amount of charge flow be calculated based on changes in the amounts of reactants and products in an electrochemical cell?
10. What is the relationship between cell conditions and changes in cell potential?
11. How do standard cell potential and constituent half-reactions within a cell predict whether an electrochemical cell is thermodynamically favored?
12. What electrochemical cell characteristics affect the amount of product that is formed at the electrodes during electrolysis?
13. How is electroplating done and what are its benefits in different industries?

HS.C.PS3.B: CONSERVATION OF ENERGY AND ENERGY TRANSFER: *What is meant by conservation of energy? How is energy transferred between objects or systems?*
1. What are the steps of an investigation that will provide the data needed to calculate the q of a system undergoing a chemical or physical change?
2. Under what conditions would molar enthalpy of reaction, average bond energies, and/or standard enthalpies of formation be used to calculate the heat of a system, q?
3. How do enthalpies of individual steps of a chemical or physical process relate to the enthalpy of the overall process?

HS.C.PS4.B: ELECTROMAGNETIC RADIATION: *What is light? How can one explain the varied effects that involve light? What other forms of electromagnetic radiation are there?*
1. How does the electronic transition in an atom or molecule give rise to the properties of an adsorbed or emitted photon?
2. What is the impact of concentration, path length, and/or molar absorptivity on the amount of light absorbed by a solution of molecules or ions?

HS.C.PSO: ORGANIC CHEMISTRY:
1. What is the importance and purpose of functional groups in organic reactions?
2. What information is needed to identify each type of macromolecule used by living things?

3. What is an isomer and how can it be modeled?
4. How can the isomeric relationship of molecules be determined?

HS.C.PSH: HUMAN IMPACT ON THE ENVIRONMENT:
1. How do chemical reactions involving greenhouse gases affect the Earth’s temperature?
2. How does energy consumption relate to global warming?
3. How might forever chemicals (PFAS) be isolated or removed from the environment?

Optional Disciplinary Specialization in Earth and Space Science Standards for Grades 7-12 Science Teachers

HS.E.VESF 1/ESS2.A: EARTH MATERIALS AND SYSTEMS:
1. How can the dynamo model be used to explain the Earth’s magnetic field?
2. What data can be used to infer the physical and chemical composition of the core?
3. What arguments can be made to support the hypothesis that the Earth’s magnetic field changes on different time scales?

HS.E.VESF 2/ESS2.B: PLATE TECTONICS AND LARGE-SCALE SYSTEM INTERACTIONS:
1. What data can be used to support a claim for when and in what patterns of plate tectonics developed through time on Earth?
2. How can a quantitative model explain the coevolution or coupling of plate tectonics and mantle convection?
3. What data can be used to support an argument from evidence for the timing of the onset plate tectonics as it operates today? (Data may include geochronology, seismic studies, paleomagnetism, topographic features, and characteristic geologic materials)

HS.E.VESF 3/ESS2.A: EARTH MATERIALS AND SYSTEMS AND ESS3.A NATURAL RESOURCES:
1. What evidence supports the hypothesis that the uneven distribution of critical elements is the result of past and current geoscience processes?
2. What are the critical elements needed for a habitable planet, carbon-free energy, or materials for a modern society?
3. What processes mobilize critical elements through Earth's systems? (Including magmatism, metamorphism, hydrothermal fluids, weathering, and sedimentation)
4. What roles do critical elements play in Earth history and/or in a modern society?

HS.E.VESF 4/ESS3.B: NATURAL HAZARDS:
1. What geoscience data can be used to support or refute a claim that not all earthquakes follow the Elastic Rebound model?
2. What are the characteristics of earthquakes and the dynamics that drive them? (Including aseismic slip and slow, intermediate and fast rupture)
3. What evidence can be used to construct a scientific explanation for how the occurrence of aseismic slip and slow, intermediate, and fast earthquakes have influenced human activity?

HS.E.VESF 5/ESS2.B: PLATE TECTONICS AND LARGE-SCALE SYSTEM INTERACTIONS:

1. What evidence can be used to construct a scientific explanation on how large, rare volcanic eruptions modify Earth Systems?
2. What are the characteristics and examples of large eruptions? (Including of 10cubic km or larger, such as Laki, supervolcanoes, and flood basalts)
3. What are the characteristics and potential impacts of large igneous provinces and their role in mass extinctions? (Including spatial and temporal scales)

HS.E.VESF 8/ESS2.D: WEATHER AND CLIMATE:

1. What data from Earth's past can be used as evidence of the dynamics of the climate system and be used to predict future change?
2. How can models of paleoclimatic and current climatic change be used to develop an argument that specific regions within Earth Systems are particularly vulnerable to rapid and/or sustained changes? (Including coastal and polar regions)
3. What evidence can be used to construct an argument about how feedback loops that operated in the geologic record are similar to or different from those occurring today? (Including permafrost melting, polar amplification and other environmental changes.)

HS.E.VESF 9/ESS2.C: THE ROLES OF WATER IN EARTH'S SURFACE PROCESSES:

1. What evidence can be used to develop an argument that the Earth's water cycle is changing?
2. What evidence can be used to support or refute a claim about how a changing water cycle will shift the availability of water for human needs? (Including hydropower, agriculture, water supply)
3. What evidence can be used to describe the impact of climate change on the water cycle?

HS.E.VESF 10/ESS2.E: BIOGEOLOGY:

1. How do biogeochemical cycles evolve over time?
2. What evidence can be used to construct an explanation of how the biosphere has evolved and interacted with the chemical makeup of Earth's surface over geologic time?
3. What models can be used to illustrate shifting patterns in Earth's biogeochemical cycles from human activities? (Including carbon, nitrogen, phosphorous)

HS.E.VESF 11/ESS2.E: BIOGEOLOGY:

1. How do geological processes influence biodiversity?
2. What is the relationship between biodiversity and geologic processes? (Including tectonics, impacts)
3. What arguments can be made to determine a relationship between metabolic pathways and other evolutionary innovations to major changes in atmospheric and ocean chemistry and climate? (Examples of metabolic pathways may include: photorespiration, carbon fixation.)

4. What are the advantages and limitations of using ecosystem response models of past changes to predict impacts of future climate change? (Including geoclimatic, geomorphologic)
5. What is the relationship between biodiversity and human impacts? (Including mining, pollution)

HS.E.NASA/ESS1.B: EARTH AND THE SOLAR SYSTEM:
1. How did the universe and solar system form and change?
2. What drives variations in the Sun, and how do these changes impact the solar system and drive space weather?
3. How did our solar system originate and change over time?
4. How did the universe begin and evolve, and what will be its destiny?

HS.E.NASA/ESS2.E: BIOGEOLOGY:
1. How did life originate on Earth?
2. What evidence supports the existence of life beyond Earth?

Optional Disciplinary Specialization in Physics for Grades 7-12 Science Teachers

HS.P.PS1.C: NUCLEAR PROCESSES: *What forces hold nuclei together and mediate nuclear processes?*
1. What are the four fundamental forces in nature, and how do they give rise to the variety of interactions that can be observed experimentally as well as those observed in everyday life?
2. In what ways is understanding radioactive decay helpful to conceptualize the broader issues facing society?
3. What types of experiments can be used to demonstrate that mass can be converted to energy and energy can be converted to mass?

HS.P.PS2.A: FORCES AND MOTION: *How can one predict an object's continued motion, changes in motion, or stability?*
1. How does torque analysis provide insight into the forces acting on an object in equilibrium?
2. How can we use the mathematical tools of calculus to gain insight into rotational velocity and rotational acceleration?
3. What types of situations are usefully analyzed with the help of the Principle of Angular Momentum Conservation?
4. What are the similarities and differences in the way pendulum and simple mass and spring systems behave as oscillators?
5. When modeling a system, in what situations is pressure a more useful variable to focus on than force?
6. How can free body diagrams be used to help predict the size of a force that is needed to cause low density objects to be completely submerged in a fluid?
7. How can Archimedes's Principle be used to understand why a solid piece of steel will sink in water but a carefully constructed ship of steel can float?
8. What are some real-world applications of the conservation of mass flow rate in fluids?

9. How does using a wave function to describe particle motion differ from using a classical trajectory to describe particle motion?

HS.P.PS2.B: TYPES OF INTERACTIONS: *What underlying forces explain the variety of interactions observed?*

1. How can understanding the nature of the electric potential provide insight into the forces experienced by charges in an electric field?
2. What are the differences between the electric potential associated with a point charge and that associated with a uniform electric field?
3. For what types of problems is Gauss's Law helpful in determining the electric field?
4. What are the differences between the electric fields produced by uniformly charged planes, cylinders, and spheres?
5. What are the differences between the electric potentials produced by uniformly charged planes, cylinders, and spheres?
6. What information about a system does the electric permittivity provide?
7. How can the principle of conservation of energy be used to make predictions about the motion of charged particles in an electric field?
8. What does the mathematical expression of the force law for a point charge in a magnetic field demonstrate about the nature of that magnetic force?
9. What model describes the magnetic field created by electric current in a long straight wire? What model expresses the force the same long, straight wire experiences in the presence of another magnetic field?
10. In what situations is Ampere's Law helpful in calculating the magnetic field, and in what cases is the Biot-Savart Law more appropriate?
11. What are some practical applications of Faraday's Law?
12. What features of Maxwell's equations suggest that electromagnetic waves can exist in vacuum?

HS.P.PS3.B: Conservation of Energy and Energy Transfer*:* *What is meant by conservation of energy? How is energy transferred between objects or systems?*

1. For an object that rolls without slipping, how does the distribution of its mass affect the proportion of its total kinetic energy that is associated with rotational kinetic energy?
2. How is the Bernoulli equation used to model fluid flow in simple systems?
3. Under which circumstances is the pressure in a system directly proportional to its absolute temperature and when is the pressure inversely proportional to its volume?
4. What role does pressure play in the transfer of energy to and from a gas?
5. What are the similarities and differences in the mathematical models of heat flow by conduction, convection, and radiation?
6. What types of processes can change the internal energy of a substance?
7. In what ways is understanding thermal conductivity useful when designing practical devices?
8. How does an understanding of entropy facilitate predictions of the evolution of thermodynamic systems over time?
9. How is power calculated for a resistor in a circuit, and what energy transformation does that describe?

10. What is the physical basis for the difference in the behavior of two resistors when they are connected in series as opposed to in parallel? What is the physical basis for the difference in the behavior of two batteries when they are connected in series as opposed to in parallel?
11. What is the connection between Kirchhoff's Loop rule and the concept of conservative force?
12. What is the connection between Kirchhoff's Junction rule and the Conservation of Electric Charge?
13. What are some examples of how energy stored in a capacitor can be used?
14. How can Faraday's Law and Lenz's Law help us understand the behavior of a circuit consisting of a battery, an inductor, a resistor, and switch, all in series?

HS.P.PHY4.B: ELECTROMAGNETIC RADIATION: *What is light? How can one explain the varied effects that involve light? What other forms of electromagnetic radiation are there?*
1. How are experiments designed differently if one wants to see the wavelike property of electrons rather than the particle-like properties?
2. In what way does quantum physics provide us with a model for explaining the results of typical photoelectric effect experiments?

HS.P.PHY4.C: INFORMATION TECHNOLOGIES AND INSTRUMENTATION: *How are instruments that transmit and detect waves used to extend human senses?*
1. How can mirrors and lenses be used to manipulate images, changing their location, size and orientation?
2. How do the properties of slit(s) and light waves affect the resulting patterns produced in interference and diffraction experiments?

Middle Grades and High School Science Teacher Preparation Standards Framework

SBE PRESENTATION DRAFT

Rationale for Faceted Standards

When we define the knowledge needed to teach science (one facet), we are left with the question of how deeply does one need to understand those core teaching ideas to engage students productively? We can imagine a teacher candidate who has mastered the ability to answer multiple choice questions about science concepts and educational theory that may not be at all prepared to teach students and use that knowledge for productive teaching and learning.

We can answer the question of how deeply we need to understand core knowledge for teaching by asking what the precise things are that a typical teacher needs to do with that knowledge, and the answer becomes, "a teacher needs to understand the core ideas well enough, deeply enough to engage in the key practices of teaching." This second facet helps us to set a depth of knowledge and a performance expectation by which we can assess if a teacher has the requisite depth of understanding. The question moves away from whether teachers have memorized core knowledge about science and the teaching of science and toward whether they can use that knowledge to effectively enact teaching practices.

Why then layer on the third facet of "guiding principles?" A teacher must be able to enact teaching practices in a way that not only demonstrates depth of core knowledge but a flexibility to use that knowledge in varied circumstances according to a set of shared principles. These principles allow candidates to develop a mindful lens for decision-making in a variety of situations that span the educational context to promote science learning for all students. Problem-solving in the context of core knowledge and core practices requires the demonstration of familiarity, understanding and capacity to reflect important guiding principles.

Facet Definitions Table

Science Teaching Practices Facet	Core Knowledge for Teaching Science Facet	Guiding Principles for Teaching Science Facet
	Definitions	
The Science Teaching Practices are the activities of teaching which are essential for: • engaging students in learning science • supporting students' social emotional development	*Core Knowledge for Teaching Science* reflects specialized knowledge for teaching: • fundamental concepts, principles, and processes in each of the subdisciplines of science, and of engineering to address scientific problems or issues • how students, depending upon age and experience, develop	*The Guiding Principles for Teaching Science* are intellectual tools and critical dispositions that: • serve as a productive lens through which teachers can organize their thinking when making decisions about all aspects of science teaching and learning

• ensuring responsible, safe science teaching practice	understanding of key scientific concepts, both in terms of breadth and depth • approaches to representing these concepts, principles and processes in ways more likely to support student learning in a safe environment	• provide teachers with an ethical framework and useful schema to make professional judgements and participate as a member of the profession

The Facets		
Science Teaching Practices	**Core Knowledge for Teaching Science**	**Guiding Principles for Teaching Science**
1. **Building respectful relationships** 2. **Eliciting and interpreting students' thinking** about science phenomena or solving problems 3. **Engaging students in sense-making** cycles of activity to explain phenomenon or solve problems 4. **Leading science discourse** in order to make sense of phenomenon or solve problems 5. Setting up and managing **small group work** to develop understanding of problems or phenomena 6. **Checking student understanding** and scientific sense-making during and at the conclusion of lessons 7. **Providing oral and written feedback** to students about phenomena or scientific problems 8. **Learning about students**' cultural, religious, family, intellectual, personal experiences, and resources for mindful/intentional inclusion in science instruction	A. **Learners and Learning Environments** - teachers understand how to create and sustain learning environments which are safe and inclusive and which engage students in powerful learning experiences to support their developing ability to make sense of scientific phenomena B. **Content Pedagogy -** teachers understand how to represent and assess scientific knowledge and practices in ways which are responsive to students' backgrounds, needs, and interests and support their ability to effectively solve problems within and across disciplines C. **Safety**- teachers understand how to produce, maintain, and evaluate the safety procedures of the grade band and disciplines D. **Impact on Student Learning -** teachers understand how to design and make use of formative and summative assessments to make informed decisions about student achievement and about instruction in the immediate and longer term E. **Professional Knowledge and Skills -** teachers understand the role of critical reflection and ongoing professional learning on instructional effectiveness F. **Specialized Content Knowledge** - teachers understand all dimensions of the key standards and progressions critical to their grade band and disciplines	I. **Science for All** - teachers are guided by the value that all students have a rightful presence in science II. **Whole Child Framework**- teachers are guided by the tenets of the whole child framework III. **Scientific Agency** - teachers are guided by recognition of the importance of building scientific agency within themselves and students IV. **Disciplinary Literacy** - teachers are guided by a stance that honest communication is critical to doing science and that teachers are responsible for apprenticing their students in that communication V. **Community Knowledge Building** - teachers will be guided by the orientation that scientific knowledge is socially constructed

Facet Elements

Science Teaching Practices Facet Elements

1. **Building respectful relationships**
   a. Establish rapport with students.
   b. Build mutual trust.
   c. Implement strategies for creating a classroom culture that values productive struggle, challenging science ideas, constructing science meaning together, and enjoying science.
   d. Monitor and maintain relationships with students.
   e. Develop classroom discussion norms with students or developing student input on established community norms that include talk that is focused on reasoning, talk that is respectful, and talk that is equitable.
   f. Examine and manage self in relationship with students.

2. **Eliciting and interpreting students' thinking** to develop scientific understanding of phenomenon or solve problems
   a. Anticipate student thinking and potential alternative conceptions of science content based on research.
   b. Formulate and pose carefully chosen questions or tasks to allow students to share their thinking about academic content in order to understand student thinking.
   c. During instruction engage students with additional questions, prompts, and tasks to probe their thinking about evidence and unpack what they say.
   d. Uncover and consider students' verbal and visible thinking to reveal novel points of view, new or alternative ideas, partial understandings, and students' everyday language and experiences to benefit future instruction.
   e. Interpret student ideas to guide instructional decisions and reveal ideas that may benefit other students.
   f. Engage students to make their thinking public.

3. **Engaging students in sense-making** cycles of activity to explain phenomenon or solve problems
   a. Unpack the big ideas, identify anchoring event, tie the essential question to the anchoring event, recognize the sense-making that occurs within the unit to develop the storyline.
   b. Engage students in questioning about a phenomenon or problem.
   c. Select and modify instructional materials to create learning environments that engage learners in using the disciplinary core ideas, science and engineering practices and crosscutting concepts to explore, describe, and explain phenomena.
   d. Engage students in using science and engineering practices and crosscutting concepts to make sense of a phenomenon or solve a problem.
   e. Support students to interpret evidence, construct explanations, and support explanations with arguments about phenomena or problems.
   f. Support students to connect experiences back to the phenomena or problem in the unit.

g. Prepare to allow students to use their everyday language to engage in discourse with new content/phenomenon and encouraging the use of technical vocabulary over the course of an instructional unit/cycle.

4. **Leading science discourse** in order to make sense of phenomenon or solve problems
   a. Plan intentionally for discourse with multiple access points.
   b. Determine the goal of the classroom discourse you expect students to engage in.
   c. Anticipate students' responses to a question or task (e.g. phenomenon, reading, data) in order to prepare to facilitate conversations.
   d. Ensure a safe and collaborative environment by revisiting and reflecting on the norms as necessary.
   e. Activate and elicit students' ideas about a science phenomenon.
   f. Support students to persevere in making sense of new observations, information or data.
   g. Press students for evidence based explanations about a phenomenon or problem.
   h. Use tools and strategies to ensure all students have equitable opportunities to participate and share their thinking (norms, talk moves, high cognitive demand tasks).
   i. Encourage students to use their everyday language to engage in discourse with new content/phenomenon.

5. Setting up and managing **small group work** to develop understanding of problems or phenomena
   a. Ensure that group tasks and structures allow students to see one another as capable contributors to their learning with understanding that group work, students' relationships, identities, and perceptions of one another affect their learning opportunities.
   b. Develop groups intentionally for appropriate size and student representation and based on patterns of student interaction.
   c. Ensure that small group work is intentionally based around high cognitive demand sense-making tasks.
   d. Establish roles and routines, monitoring and coaching and providing feedback on implementation.
   e. Provide the strategies and tools, written and verbal instructions, as well as scaffolds for students to engage in discourse within a task.
   f. Use student and group roles to foster discourse about the phenomenon and problems posed by the group task.
   g. Monitor small group work to ensure that the individual student's understanding and group understanding are both critical to the work and valued.
   h. Make adjustments based on observations of individual students, groups, and their sense-making.

6. **Checking student understanding** and scientific sense-making during and at the conclusion of lessons
    a. Elicit student thinking through tools such as summary tables, KLEWS charts, driving question boards or others that enable students to think critically about the lesson phenomenon and work to understand how the students' current thinking helps explain the anchoring phenomenon or solve a problem.
    b. Use or modify both formative and summative assessments that elicit evidence of the three dimensional aspects of student science understanding.
    c. Reflect and interpret student thinking and understanding.
    d. Inform and adjust instruction based on student thinking and understanding.

7. **Providing oral and written feedback** to students about phenomena or scientific problems
    a. Prepare constructive written feedback to students that continues to strengthen relationships and move students toward productive sense-making.
    b. Give specific feedback in a timely fashion to support student thinking and affirm student knowledge and skills.
    c. Use appropriate guiding questions and productive talk to guide students to reflect on understanding in all three science dimensions and encourage them to go deeper.
    d. Provide equitable and valuable feedback to empower learning and promote ownership and agency.
    e. Provide opportunities for students to self-assess, use feedback and give feedback to each other.
    f. Support and monitor students' response to the feedback.

8. **Learning about students**' cultural, religious, family, intellectual, personal experiences, and resources for use in science instruction
    a. Make intentional connections through use of talk moves to encourage students to share with the class or small group how they can relate to the phenomenon or situation personally.
    b. Ensure tasks (assessments and activities) are equitable for the diversity of students in your care.
    c. Learn your students' background, and use this information as you plan for and adapt instruction.
    d. Create opportunities for students to engage in diverse sense-making building on their community histories, values, and practices.
    e. Design learning experiences to grow out of the lives of learners.
    f. Support students to use their sense-making repertoires and experiences as critical tools in engaging with science practices.
    g. Notice sense-making repertoires and consider students' diverse sense-making as connecting to science practices.

CORE KNOWLEDGE FACET ELEMENTS

CK A: Learners and Learning Environments

Well-prepared beginning science teachers will understand:

1. how learners make sense of scientific phenomena, ideas, experiences and data, what scientific sense-making looks like in individuals, and the iterative nature of sense-making.
2. appropriate and engaging teaching and learning strategies for creating a classroom culture that values productive struggle, challenging science ideas, engaging in productive science discourse, constructing science meaning together, and enjoying science.
3. appropriate and engaging learning activities that foster an inclusive, equitable, and anti-bias environment and create an inclusive linguistic culture.
4. appropriate and engaging learning activities in a variety of environments (e.g., the laboratory, field, and community).
5. appropriate and engaging learning activities to include in lesson sequences and/or assessments to create learning environments that provide opportunities for sense-making and explanation building through investigation, collaboration, communication, evaluation, revision, modeling and argumentation related to scientific phenomena.

CK B: Content Pedagogy

Well-prepared beginning science teachers will understand:

1. the role of scientific phenomena and problems in three-dimensional teaching and learning and their role in connecting science disciplines.
2. appropriate research-based student-centered, culturally-relevant, disciplinary-based 3D instructional approaches; leveraging learners' prior experiences and knowledge, varying activity structures, talk and group work for science. For example, they should be expected to elicit learners' thinking, cultural and community connections, and curiosity when making sense of phenomena.
3. appropriate differentiation strategies and research-based pedagogical strategies to support students with a variety of cognitive, emotional, physical and other needs and strengths so that all students develop conceptual knowledge.
4. engagement of students in applying science practices and crosscutting concepts, such as clarifying relationships, and identifying natural patterns from empirical experiences in lessons, curricula and assessments.
5. engineering practices wherein students design, construct, test and optimize possible solutions to a problem in support of science learning and how it is similar or different from science.
6. alignment of instruction and assessment strategies which address students' prior knowledge and *alternative* conceptions to support instructional decision-making and navigate tensions between alternative ideas and ways of knowing (which may be derived from various cultures) and canonical science ideas. Example strategies include: referring to evidence, continuing to consider/debate to work through the ideas, focusing on the most important disciplinary/explanatory ideas and understanding when it is appropriate and necessary to create space for learners to grapple with alternative ideas.

7. integration of science-specific technologies to support all students' conceptual understanding of science and engineering.
8. appropriate instructional strategies which illustrate the interdisciplinary nature of fundamental principles, processes and problems in science and engineering.
9. connections to other core disciplines (mathematics, social studies and English language arts) within the science standards.

CK C: Safety

Well-prepared beginning science teachers will understand:

1. activities appropriate for the abilities of students that demonstrate safe techniques for the procurement, preparation, use, storage, dispensing, supervision, and disposal of all chemicals/materials/equipment used within their grade band and disciplines.
2. how to recognize hazardous situations including overcrowding; implement emergency procedures; maintain safety equipment; provide adequate student instruction and supervision; and follow policies and procedures that comply with established state and national guidelines, appropriate legal state and national safety standards (e.g., OSHA, NFPA, EPA), and best professional practices (e.g., NSTA, NSELA).
3. ethical decision-making with respect to safe and humane treatment of all living organisms in and out of the classroom, and compliance with the legal restrictions and best professional practices on the collection, care, and use of living organisms as relevant to their grade band and disciplines.

CK D: Impact on Student Learning

Well-prepared beginning science teachers will understand how to:

1. use assessments that show students have learned and can apply disciplinary knowledge, nature of science, science and engineering practices, and crosscutting concepts in practical, authentic, and real-world situations.
2. use summative purposeful disaggregated assessment data or information to inform future planning and teaching, with particular attention to student demographics and learning progress.
3. use formative assessments to recognize and assess learners' ideas, life experiences and learning beyond the technical scientific language by evaluating samples of learners' work and classroom interactions to determine the nature and depth of learner sense-making and leverage ongoing changes in student's learning to adjust instruction.

CK E: Professional Knowledge and Skills

Well-prepared beginning science teachers will understand:

1. critical reflection on science teaching to continually improve instructional effectiveness.
2. accessing specific opportunities for professional development to deepen their science-specific content knowledge and pedagogical knowledge as well as practices.

CK F: Specialized Content Knowledge

Well-prepared beginning science teachers will understand:

1. the nature of science and the cultural norms and values inherent to the current and historical development of scientific knowledge.
2. crosscutting concepts, disciplinary core ideas, practices of science and engineering, the supporting role of science-specific technologies, and contributions of diverse populations to science.
3. science standards, learning progressions, and sequencing of science content for teaching the appropriate grade band and discipline area.
4. grade appropriate elements of the practices, disciplinary core ideas, and cross-cutting concepts within instructional materials.
5. the major concepts, principles, theories, laws, and interrelationships of their grade band and disciplines and supporting fields (e.g., mathematics).

GUIDING PRINCIPLES FACET ELEMENTS

I. Science for All - Teachers are guided by the value that all students have a rightful presence in science.

A. Science is a culturally mediated way of thinking and knowing and may contribute to and/or disrupt social inequities over time.
B. Social and critical justice orientation propels teachers to recognize and disrupt systemic injustices and inequities manifested in classroom practices.
C. Multicultural representations and respect for culturally different ways of knowing reinforce students' rightful presence in science, and expand students' funds of knowledge of the multicultural contributions to the field.
D. Pedagogies that are culturally sustaining can be used to leverage and enhance scientific ways of thinking and to respect students' cultures.
E. Social capital can be mobilized to ensure opportunities for higher order and complex thinking for all students in science across school systems.

II. Whole Child Framework- Teachers are guided by the tenets of the whole child framework.

A. Each student learns in an environment that is physically safe, adhering strictly to science safety protocols, while also emotionally safe for intellectual risk taking and building a culture that supports public reasoning (Safety).
B. Each student's development in using science and engineering practices and crosscutting concepts is supported by a caring adult through leveraging community resources and scaffolded sense-making (Supported).
C. Each student is actively engaged in science and engineering practices and using crosscutting concepts as they solve problems in their school and broader communities (Engaged).
D. Each student has access to high-level challenges that build citizenship, stewardship, and lifelong engagement to ensure access to future school and career opportunities in STEM fields (Challenged).

III. Scientific Agency - Teachers are guided by recognition of the importance of building scientific agency within themselves and students

A. Building and promoting positive science identities is prioritized.
B. Students understand the nature of science and then improve their ability to navigate and explain their world by actively engaging in science.
C. Learning is best situated within students' lived experiences, building on existing student ideas, assets, resources, and ways of knowing.
D. Assessments could be tied to negative outcomes on students' identity as scientists. Teachers must be thoughtful with regard to modalities, feedback and how assessment information is used.
E. Students demonstrate understanding in different, valid, and informative ways and it is necessary to provide different options for how students show their sense-making.
F. Empowering students toward action that contributes to scientific problem solving in their community and in the world.

IV. Disciplinary Literacy -Teachers are guided by a stance that communication is critical to doing science and that teachers are responsible for apprenticing their students in that communication

A. Evidence-based skepticism is necessary for citizens to be critical consumers of science who are able to consider the complexity and dynamic nature of science.
B. Agency within a discipline is highly connected to the literacies and communication practices of that discipline.
C. Honoring multiple ways of knowing, doing, and communicating scientific thinking ensures a rightful presence in science for all students.
D. Scientific argument must transparently communicate ideas supported by credible evidence and valid reasoning.
E. Technology is an important means for obtaining, communicating and evaluating information.

V. Community Knowledge Building - Teachers will be guided by humility and the stance that scientific knowledge is socially constructed

A. Science understanding is socially constructed in an inquiry-based classroom environment where all students engage in the building of knowledge or possible solutions.
B. A scientific community ensures a collaborative evidence-based approach to addressing beliefs and biases while valuing other ways of knowing and doing science.
C. Science learning is most meaningful when situated within the community to ensure authenticity and cultural relevance as problems are solved in real-world contexts in collaboration with various stakeholders.
D. Science teachers must engage in self-reflection in order to build awareness of the impact of one's own culture and biases in the classroom and on the co-construction of knowledge.
E. Science teachers must be open to learning from students and colleagues in order to grow in their teaching, scientific understanding, and ability to be culturally responsive.

F. Science teaching must be student-centered; prioritizing student needs, perspectives, questions and problems within classroom instruction as authentic scientific work.
G. Classroom culture must promote and support risk-taking inherent in public reasoning needed for science learning.

EXAMPLES

How the facets were used to develop three-faceted performance objectives

EXAMPLE 1:

MG.S1. LEARNERS AND LEARNING ENVIRONMENTS

Well-prepared beginning teachers of science:

S1.1 Learn about, consider and incorporate students' backgrounds to plan and adapt instruction that leverages the iterative nature of sense-making and promotes positive student identities.		
Science Teaching Practices	Core Knowledge	Guiding Principles
8c: Learning about students' cultural, religious, family, intellectual, personal experiences, and resources for use in science instruction c. Learn students' background and use this information as you plan for and adapt instruction	**CK C: Learners and Learning Environments** 1. how learners make sense of scientific phenomena, ideas, experiences and data, what scientific sense-making looks like in individuals, and the iterative nature of sense-making	**IIIA: Scientific Agency** - teachers are guided by recognition of the importance of building scientific agency within themselves and students A. Building and promoting positive science identities is prioritized

EXAMPLE 2:
MG.S1. LEARNERS AND LEARNING ENVIRONMENTS
Well-prepared beginning teachers of science:

S1.2 Monitor and maintain relationships with students while engaging them in productive struggle and discourse to challenge science ideas and construct science meaning together, keeping in mind the importance of supporting each student's development through scaffolded sense-making.		
Science Teaching Practices	Core Knowledge	Guiding Principles
1d: Building respectful relationships d. Monitor and maintain relationships with students.	**CK C: Learners and Learning Environments** 2. appropriate and engaging teaching and learning strategies for creating a classroom culture that values productive struggle, challenging science ideas, engaging in productive science discourse, constructing science meaning together, and enjoying science	**IIB: Whole Child Framework** - teachers are guided by the tenets of the whole child framework. B. Each student's development in using science and engineering practices and crosscutting concepts is supported by a caring adult through leveraging community resources and scaffolded sense-making (Supported)