Utah State Office of Education
Elementary STEM Endorsement Course Framework
Nature of Science and Engineering

Course Description:

In this course participants will experience introductory explorations of the nature of science using science and engineering principles, practices, and processes. Applications to Science, Technology, Engineering and Mathematics will be explored using learner-based pedagogy. Participants will develop teaching practices to assist them in educating K-6 students in selected Earth and Life Science Standards.

Course Objectives:

● Objective #1: Content Knowledge: Develop a deeper understanding the nature of science and engineering.
  ○ Climate change and natural selection require scientific understanding and engineering solutions
  ○ Science is a way of knowing and assumes an order and consistency in natural systems.
  ○ Science addresses questions about the natural and material world while engineering addresses human problems in the natural and material world
  ○ Scientific knowledge and engineering solutions are based on empirical evidence

● Objective #2: Cross Cutting Concept: Explain that stability and change are present in all natural and built systems. Conditions of stability and rates of change or evolution of a system are critical elements of study.
  ○ Natural climate cycles and natural selection are supported by evidence.
  ○ Rate of change of any natural or built system impacts evolutionary change.
  ○ Scientific argumentation must be supported by evidence.

● Objective #3: Connect theory and practice through reflection, teaching, scholarship, and STEM educational action research. Including traditionally under-represented groups that consider students of diverse backgrounds and perspectives.
  ○ Have capacity and confidence to run a student inquiry-based classroom.
  ○ Integrate cross curricular learning.

● Objective #4: Demonstrate proficiency with STEM content, skills, and practices and teach those to students.
  ○ Communicate using multiple forms of discourse.
  ○ Develop reasoning and problem solving practices.
Facilitate effective collaboration and communication among the students.
Demonstrate proficiency in STEM content.

Objective #5: Explore and implement innovative, research-based, engaging curriculum, especially around the Utah Core academic standards and college and career readiness, geared towards increasing student achievement.
Apply the disciplinary core ideas when planning lessons and teaching.
Use cross-cutting concepts when planning lessons and teaching.
Implement scientific practices into lesson planning and teaching.

Course Construction Recommendation:

- It is recommended that this be the first course taught in the elementary STEM endorsement focusing on conceptual change of instructional strategies.
- Compare and contrast theory development with the engineering cycle. (New evidence to change theory, [Pluto], Design, test, redesign [bow and arrow]. Iterative nature of both processes should be highlighted.
- Participants will visit a scientist or engineer in their place of work. This experience should provide opportunity for the teacher to engage in scientific and engineering practices in the field.
- The participants are presented with an engineering challenge where they develop a viable solution given specific constraints and requirements.
- Using natural selection and global climate change, investigate scientific theory formation.
- Conceptually understand that theories are explanations for observable phenomena and scientific theory is based on a body of evidence developed over time.

Course Topics:

**Engineering Process Knowledge**

3-5-ETS1-1. Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.

3-5-ETS1-2. Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.

**Nature of Science**

Please see Addendum A for a more detailed outline of topics for science content that would support the main ideas highlighted below.
● Scientific Investigations Use a Variety of Methods
● Scientific Knowledge is Based on Empirical Evidence
● Scientific Knowledge is Open to Revision in Light of New Evidence
● Scientific Models, Laws, Mechanisms, and Theories Explain Natural Phenomena
● Science is a Way of Knowing
● Scientific Knowledge Assumes an Order and Consistency in Natural Systems
● Science is a Human Endeavor
● Science Addresses Questions About the Natural and Material World

Pedagogical Focus of Course:

The purpose of this course is to ensure that practicing teachers can apply the pedagogical content knowledge needed to teach STEM concepts to students in the elementary grades. Teachers must also, however, know how to transfer that content knowledge and the conceptual understandings inherent in the content to students. An understanding of sound pedagogical practice is essential to that transfer. There are a variety of pedagogical concepts and strategies that should be infused into the courses to aid teachers in student instruction. These concepts should never be taught in isolation, but should be modeled throughout the course to create a student-centered learning environment in which students use hands-on investigations, engineer solutions to problems, and construct evidence-based explanations of real-world phenomena.

Knowledge of STEM for course participants:

● Patterns
  Observed patterns of forms and events guide organization and classification, and they prompt questions about relationships and the factors that influence them.

● Cause and Effect:
  Mechanism and Explanation. Events have causes, sometimes simple, sometimes multifaceted. A major activity of science is investigating and explaining causal relationships and the mechanisms by which they are mediated. Such mechanisms can then be tested across given contexts and used to predict and explain events in new contexts.

● Scale, Proportion, and Quantity
  In considering phenomena, it is critical to recognize what is relevant at different measures of size, time, and energy and to recognize how changes in scale, proportion, or quantity affect a system’s structure or performance.

● Systems and System Models
  Defining the system under study—specifying its boundaries and making explicit a model of that system—provides tools for understanding and testing ideas that are applicable throughout science and engineering.
- **Energy and Matter: Flows, cycles and conservations.**
  Defining the system under study—specifying its boundaries and making explicit a model of that system—provides tools for understanding and testing ideas that are applicable throughout science and engineering.
- **Structure and Function**
  The way in which an object or living thing is shaped and its substructure determine many of its properties and functions.
- **Stability and Change**
  For natural and built systems alike, conditions of stability and determinants of rates of change or evolution of a system are critical elements of study.

**Effective STEM teaching practices:**

- Ability to Ask Scientific Questions and Define Problems
- Ability to Plan and Carry Out Investigations
- Ability to Analyze, Interpret Data, and Make Predictions
- Ability to Develop and Use Models
- Ability to Construct Explanations and Design Solutions
- Ability to Engage in Argument from Evidence
- Ability to Use Mathematical and Computational Thinking
- Ability to Obtain, Evaluate and Communicate Information

**Knowledge of STEM curriculum and assessment:**

1. Understandings of science content and process knowledge and skills
2. Abilities to think critically and solve simple to complex problems
3. Capabilities of designing scientific experiments, analyzing data, and drawing conclusions
4. Capacities to see and articulate relationships between science topics and real-world issues and concerns
5. Skills using mathematics as a tool for science learning
(Above are from NSTA position statement on assessment)
6. Demonstrate creative thinking, construct knowledge, and develop innovative products and processes using technology.
7. Apply digital tools to gather, evaluate, and use information
8. Use digital media and environments to communicate and work collaboratively, including at a distance, to support individual learning and contribute to the learning of others.
9. Use critical thinking skills to plan and conduct research, manage projects, solve problems, and make informed decisions using appropriate digital tools and resources.
10. Understand human, cultural, and societal issues related to technology and practice legal and ethical behavior.
11. Demonstrate a sound understanding of technology concepts, systems, and operations.
(Above are from ISTE student standards)
12. Select, use, adapt and determine the suitability of STEM curricula and teaching materials (e.g., textbooks, technology, manipulatives) for particular learning goals.
13. Be cognizant of a formative assessment cycle (administering a formative assessment, analyzing student work from the assessment, using that analysis to enhance teacher knowledge, and designing and teaching re-engagement lessons) and resources.
14. Provide appropriate interpretations of assessment results, and communicate results (in context) to specific individuals and groups (e.g., students, parents, caregivers, colleagues, administrators, policy makers, community members).
(Above are from AMTE Standards for Elementary Mathematics Specialists)

Possible Assignments:

- Participants will visit a scientist or engineer in their place of work and engage in discourse and activities.
- Investigate human impacts on the environment. Identify ways to collect data and design an engineering solution to mediate negative impacts.
- Collect and analyze data that provides evidence of science phenomenon such as natural selection, inheritance of traits, climate change, biodiversity etc.
- Develop evidence based arguments to justify theories of natural selection, inheritance of traits, climate change, biodiversity etc.
- Design engineering solutions related to human impact on Earth systems, including climate change and reduced biodiversity.
- Implementation of 3 of the “model lessons” in teachers’ classrooms. Followed by a reflection, including pictures.
- Reflection paper documenting the observed activities of the professional/practitioner and the science/engineering practices presented in class.
- Reading research – choose from possible articles and do an assignment based on the article; discussions, agreement/disagreement, impact in classrooms.

Possible Internships or Experiential Learning Recommendations:

- It is suggested that the internship experience consists of opportunities to interact with a science/engineering professional. This experience should provide opportunity for the teacher to engage in scientific and engineering practices in the field.

Suggested Resources:


## Addendum A:


### Understandings about the Nature of Science

<table>
<thead>
<tr>
<th>Categories</th>
<th>K-2</th>
<th>3-5</th>
<th>Middle School</th>
<th>High School</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scientific Investigations Use a Variety of Methods</td>
<td>• Scientists make observations/measurements and develop explanations.</td>
<td>• Scientists make observations/measurements and develop explanations.</td>
<td>• Scientists use evidence to develop explanations and underlying assumptions.</td>
<td>• Scientists use evidence to develop explanations and underlying assumptions.</td>
</tr>
<tr>
<td>Scientific Knowledge is Based on Empirical Evidence</td>
<td>• Scientists look for patterns and make observations/measurements that can be explained.</td>
<td>• Scientists make observations/measurements and develop explanations based on evidence.</td>
<td>• Scientists make observations/measurements and develop explanations based on evidence.</td>
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</tr>
<tr>
<td>Scientific Knowledge is Open to Revision in Light of New Evidence</td>
<td>• Science knowledge can change when new information is found.</td>
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<td>• Science knowledge can change when new evidence is found.</td>
</tr>
<tr>
<td>Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena</td>
<td>• Scientists use models, data, and models as a way to communicate ideas.</td>
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</tr>
</tbody>
</table>

### Overview

One goal of science education is to help students understand the nature of scientific knowledge. This matrix presents eight major themes and grade level understandings about the nature of science. Four themes extend the scientific and engineering practices and four themes extend the crosscutting concepts. These eight themes are presented in the left column. The matrix describes learning outcomes for the themes at grade bands for K-2, 3-5, middle school, and high school. Appropriate learning outcomes are expressed in selected performance expectations and presented in the foundation boxes throughout the standards.
Below are suggested course topics to help contextualize discussions about the nature of science.

**ESS3.C Human impacts on Earth systems**

- **(K-2)** Things people do can affect the environment but they can make choices to reduce their impacts.
- **(3-5)** Things people do can affect the environment but they can make choices to reduce their impacts.
- **(6-8)** Human activities have altered the biosphere, sometimes damaging it, although changes to environments can have different impacts for different living things. Activities and technologies can be engineered to reduce people's impacts on Earth.

**ESS3.D Global climate change**

- **(6-8)** Human activities affect global warming. Decisions to reduce the impact
of global warming depend on understanding climate science, engineering capabilities, and social dynamics.

LS2.C Ecosystem dynamics, functioning and resilience

- (K-2) NA
- (3-5) When the environment changes some organisms survive and reproduce, some move to new locations, some move into the transformed environment, and some die.
- (6-8) Ecosystem characteristics vary over time. Disruptions to any part of an ecosystem can lead to shifts in all of its populations. The completeness or integrity of an ecosystem's biodiversity is often used as a measure of its health.

LS2.D Social interactions and group behavior

- (K-2) N/A
- (3-5) Being part of a group helps animals obtain food, defend themselves, and cope with changes.
- (6-8) NA

LS3.A Inheritance of traits LS3.B Variation of traits

- (K-2) Young organisms are very much, but not exactly, like their parents and also resemble other organisms of the same kind.
- (3-5) Different organisms vary in how they look and function because they have different inherited information; the environment also affects the traits that an organism develops.
- (6-8) Genes chiefly regulate a specific protein, which affect an individual's traits.
- In sexual reproduction, each parent contributes half of the genes acquired by the offspring resulting in variation between parent and offspring. Genetic information can be altered because of mutations, which may result in beneficial, negative, or no change to proteins in or traits of an organism.

LS4.A Evidence of common ancestry and diversity

- (K-2) NA
- (3-5) Some living organisms resemble organisms that once lived on Earth. Fossils provide evidence about the types of organisms and environments that existed long ago.
● (6-8) The fossil record documents the existence, diversity, extinction, and change of many life forms and their environments through Earth's history. The fossil record and comparisons of anatomical similarities between organisms enables the inference of lines of evolutionary descent.

LS4.B Natural selection

● (K-2) NA
● (3-5) Differences in characteristics between individuals of the same species provide advantages in surviving and reproducing.
● (6-8) Both natural and artificial selection result from certain traits giving some individuals an advantage in surviving and reproducing, leading to predominance of certain traits in a population.

LS4.C Adaptation

● (K-2) NA
● (3-5) Particular organisms can only survive in particular environments.
● (6-8) Species can change over time in response to changes in environmental conditions through adaptation by natural selection acting over generations. Traits that support successful survival and reproduction in the new environment become more common.

LS4.D Biodiversity and Humans

● (K-2) A range of different organisms lives in different places.
● (3-5) Populations of organisms live in a variety of habitats. Change in those habitats affects the organisms living there.
● (6-8) Changes in biodiversity can influence humans’ resources and ecosystem services they rely on.