DETERMINING THE APPROACH TO ELEMENTARY CLIMATE EDUCATION USING NEXT GENERATION SCIENCE STANDARDS

by

Fiona Gain

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Executive Summary

This project discusses the need for increased climate education through inquiry and action among the nation’s youngest learners and potential action-takers. The Energy Policy and Climate (EPC) program offers insight into the data and methodologies that drive policy creation and application. Certain courses, like Climate Change and Health and Climate Justice, devote modules that speak to the importance of climate education for the success of climate policy and action. In most discussions that occur within the EPC program, students and faculty alike make a similar conclusion: if the public is not motivated to comply or help with climate actions, society will be worse off.

Knowing how children understand climate change and how they relate to the mounting discussions and actions about the climate can help educators design and execute curriculum that clears misconceptions and furthers children's perception of the climate. Climate education is often directed at older members of society who have more influence on the institutions and organizations responsible for climate action. However, formulating an approach to climate education for elementary school students seizes the opportunity to inform and shape the views of the upcoming generation of scientists, policy makers, and enfranchised citizens.

The approach to climate education in elementary schools requires systems learning that explains the climate crisis with a tone that avoids doomism without becoming overly optimistic. Executing a literature review of existing analyses or case studies of elementary climate education can inform future policy for climate and environmental education, which may include changes to learning plans, science teacher training for content and approach, and the inclusion of climate-explicit learning standards. In addition, a curriculum proposal based on existing literature can be used by educators to reference during the expansion of science standards to include climate change.
Introduction

Climate change education is essential for developing positive climate attitudes among the public. While perception of climate change is heavily dependent on educational jurisdictions and culture, quality climate education can transform understanding.¹ Climate change curriculum can be integrated into interdisciplinary learning at the K-5 level in the context of the Next Generation Science Standards, the most current set of science curriculum for K-12 development. Research taken from case studies that have attempted interdisciplinary, climate-focused instruction in conjunction with guidance from the nationally accepted Next Generation Science Standards informed the creation of the example unit in an attempt to create an informative climate module for both teachers and students.

Holistic and buildable climate change education on a K-5 scale extends the fundamentals of primary school content within a learning environment that acknowledges the context of climate change. The development of climate change education is critical for preparing students for the world in the context of the negative effects of climate change and further prepares them for multidisciplinary problem-solving and learning. Climate science education is a fairly new development in early education. Despite climate change becoming a more thoroughly examined subject on the K-5 level, formalized curriculum and studies on the benefits of a cross-disciplinary, climate-oriented curriculum are not widely available. The increasing interest in and need for effective climate change education creates an appropriate opportunity to conduct a systematic review to understand effective strategies in climate change education.² The available literature

² Allen and Heredia. Reframing Organizational Contexts from Barriers to Levers for Teacher Learning in Science Education Reform. 13
focuses on climate education from a variety of viewpoints - teacher facing, student facing, and the overall effectiveness of climate curriculum.

Currently, information is available for teachers concerned about the barriers of workload, lack of development, and social issues preventing many teachers from effectively integrating climate change into the curriculum. There are certain commonalities in these barriers, with patterns on the inclusion of climate change lessons emerging from teacher perspectives, but solutions are offered to encourage content integration. Furthermore, misconceptions from teachers about the approach on teaching climate change science can be corrected with professional development.

Student-facing research is centered around student attitudes towards climate education, but mostly among older students. Methodology and approach towards lesson planning for climate education is assessed within university populations. The relationship between teacher and student when approaching climate content, and the social, scientific, and political lens in which students learn, is analyzed through a case study involving high school classes, climate scientists, and teachers. Furthermore, a framework for climate science integration is offered in conjunction with the Next Generation Science Standards.

The standards that climate content is introduced is important to understand in order to effectively produce a comprehensive, goal-reaching curriculum. To do so, an analysis of the Next Generation Science Standards, a multi-state effort in the United States for new education standards,

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3 Anderson. “Climate Change Oxarart Education for Mitigation and Adaptation”
4 Wise “Climate Change in the Classroom: Patterns, Motivations, and Barriers to Instruction Among Colorado Science Teachers.”
5 Allen and Heredia. 13
6 Walsh “An Examination of Climate Scientists’ Participation in Education: Implications for Supporting the Teaching and Learning of Socially Controversial Science”
is included in research for this proposal.\textsuperscript{8} Contrasting education standards that discourage the integration of climate science into curriculum is also assessed.\textsuperscript{9}

After a thorough assessment of available literature on the topic of climate curriculum at the K-5 level across all subjects, it proved difficult to find examples of curriculum that integrate climate science content on a primary grade level. Furthermore, while student and teacher perspectives are assessed, there are minimal recommendations about how to overcome these barriers to produce an efficient curriculum. This project will contribute to existing information on this subject by serving as a framework for inquiry-based instruction across subjects and grade levels that encourages advanced inclusion of climate science content in the classroom. The deliberate inclusion of this content will provide opportunity for intergenerational learning and the context to overcome adult biases that are present later in life.\textsuperscript{10}

Methods

The collected literature is organized into thematic sections that cover the existing literature reviewing stakeholder attitudes and pedagogical approaches to climate change education. The methodologies used will be a combination of reviewing existing literature, understanding the representative literature on climate change education and the factors that limit or encourage the successful development and integration of climate curriculum, and modeling a K-5 climate program that expands across different subjects based on the standards collected through the literature review. To acquire materials to better understand existing climate curriculum research

\textsuperscript{8} Allen and Heredia. “Reframing Organizational Contexts from Barriers to Levers for Teacher Learning in Science Education Reform”
\textsuperscript{9} Holland. “The Implementation of the Next Generation Science Standards and the Tumultuous Fight to Implement Climate Change Awareness in Science Curricula”
and case studies, the researcher found several research and journal articles using online search engines including the Johns Hopkins University Library and the Institute of Education Sciences. The research was then reviewed based on several thematic groupings: Teacher Attitudes, Student Attitudes, Pedagogical Approaches, and the Next Generation Science Standards.

Once comprehensive research had been conducted, a curriculum was developed based on unit structures like those used in a traditional elementary science setting with a perspective shift to focus on climate change. The water cycle was chosen as a topic to relate to several different elementary Next Generation Science Standards based on grade level. The methodology of the curriculum creation was based on inquiry-based, action-oriented work that motivates students to understand the systems around them and concludes with a final project to solidify students’ ability to enact change in the sphere of climate action.

Results

Teacher Attitudes and Preparedness

Improved training for elementary teachers for science and engineering instruction in terms of understanding the content taught as well as the pedagogical approaches for doing so is needed.\(^{11}\) Elementary teacher content knowledge in science and engineering is recognized as weak as compared to preparedness in other subject areas.\(^{12}\) Elementary science teachers have reservations concerning climate science concepts and this relates to their ability to successfully provide context and climate content in a way that suits elementary students’ developmental and

\(^{11}\) Science Leadership Initiative. “Supporting Elementary and Middle School Stem Education at the Whole School Level: A Review of the Literature”. 3

psychological threshold. Understanding barriers for effective climate instruction can help in designing professional development and training tools for educators to both encourage and clear preexisting conceptions of climate in educators.

The first aspect of teacher preparedness in climate change education is individual emotions and relationships with the effects of climate change and the approach to instruction. Research studies have suggested elementary school teachers tend to other the impacts of climate change and focus on the collective to explain the causes of climate change. Both the cause and the effect of climate change elicit emotional reactions from educators, and this can be utilized to offer more compelling discussions and projects in the classroom. Furthermore, research suggests that teaching about climate change requires community-based, hands-on learning opportunities. Hands-on teaching, which requires inquiry-based discovery that encourages formulation of new concepts to be scrutinized, is dissimilar to the teaching experiences of current in-service teachers. Because of the difference in instruction approaches, teachers are not keen to instruct based on inquiry and discussion formatted curriculum.

Elementary science education is oftentimes limited by the lack of real-life experience of the science concepts by teachers before they teach those concepts to students. The majority of pre-service educators take six to nine hours of science preparation courses which solidify understanding of science content, but the rest of an elementary education degree is devoted to mastering pedagogical concepts and methods of approach to education that is oriented to the

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13 Hufnagel. “Emotional Connections and Disconnections to Climate Change”. 1310
14 Nadelson, Callahan, Pyke, Hay, Dance, and Pfiester.
16 Rethinking Elementary Science Methods Course. 759
17 Nadelson, Callahan, Pyke, Hay, Dance, and Pfiester.
18 Kelly. “Rethinking the elementary science methods course: a case for content, pedagogy, and informal science education” 755.
psychological and developmental limits of elementary students.¹⁹ Many in-service science teachers agree that human activity causes climate change and will have significant consequences²⁰, but both pre-service and in-service teachers are unaware of the scope of these consequences.²¹ The lack of confidence in climate knowledge creates a population of science teachers unwilling or afraid of incorporating climate science into their curriculum. Trainings that educate teachers on the cause of climate change and the effects of climate change in the several introductory concepts elementary teachers are responsible for help destigmatize and motivate climate instruction.

**Student Attitudes**

In comparison to examining elementary teacher attitudes, evaluating primary student attitudes involves more barriers in communication, comprehension, and clarity. Instead, the success of different approaches in the primary classroom as well as testing markers of development help measure the preparedness of elementary school students for discussion and activities about climate change. Successful instruction methods exist for primary-aged students, but an analysis of these methods in the context of climate change instruction is critical for determining the depth of emotional connection and mental burden to climate change and whether this is detrimental to developing overall collective attitudes.

While students are capable of comprehending climate concepts, the implications of the changes to the climate system are difficult to understand. Most recent evidence suggests that

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¹⁹ Hufnagel. 1310  
²⁰ Howard-Jones et al. 1672  
²¹ Aksan and Celikler. “Pre-service Elementary Teachers’ Perceptions and Opinions about the Greenhouse Effect” 174
personal memories and attachment are central to the development of social capital in children.\textsuperscript{22} At even five years old, attentional styles develop that are associated with mindset and a determination of preference for an individualistic or collective scale.\textsuperscript{23} Forming personal understanding in connection to collective duty and social capital will create positive motivations for climate action throughout the course of one’s life.

Climate learning encourages “action competence” which is essential for students able to take responsibility for their own actions and those of their institutions\textsuperscript{24}. The root motivation for climate change education is to create a population of citizens willing to criticize the institutions of their society and able to develop solutions for the harmful activities those institutions are responsible for. This criticism should not be based in the political or social bias that prevent many adults from understanding climate change\textsuperscript{25}, but rather from the development of concern on behalf of the natural and social implications that come because of greenhouse gas emissions and climate change.

**Pedagogical Approaches to Elementary Climate Education**

Determining the most effective approach to climate science can be assessed within the context of general elementary science education and the value of scientific understanding at the primary school age. Students’ first experience with science should prepare them with the skill required to explore new ideas and scrutinize existing scientific perspectives.\textsuperscript{26} The learning of

\textsuperscript{22} Williams and McEwen. “‘Learning for Resilience’ as the climate changes: discussing flooding, adaptation, and agency with children”, 1640.
\textsuperscript{23} Howard-Jones, Sands, Dillon, and Fenton-Jones. 1672.
\textsuperscript{24} Ibid. 1673.
\textsuperscript{25} Nadelson, Callahan, Pyke, Hay, Dance, and Pfiester.
\textsuperscript{26} McGregor. “Dramatizing Science Learning: Findings from a pilot study to re-invigorate elementary science pedagogy for five- to seven-year-olds”
these scientific skills is essential to “stimulate curiosity, support life choices, and help future citizens be discerning about evidence and unscientific claims”. 27 Teaching climate science in particular has the capability to transform childhood attitudes to the environment, with certain studies concluding that the greatest benefits of climate understanding come from introducing principles as early as preschool and building on those principles throughout the K-12 curriculum. 28 In order to execute this, elementary science teachers need their own understanding of the science concepts and processes discussed in the classroom paired with the ability to communicate these concepts at the appropriate level. 29 While the measures of in-service teachers who feel confident in their understanding of climate concepts was discussed previously, the approach of communicating climate concepts to elementary aged students requires understanding of the influences at play inside and outside the classroom.

Within the school, faculty culture and awareness of the need for climate science can facilitate success of instruction. The lack of explicit climate standards in early science education serves as a limitation that can be resolved from support from school administrators and mission. Educators may also be unable to successfully execute climate curriculum if they are unable to access professional development tools like teacher training and relevant materials. 30 Furthermore, a pro-climate school culture encourages action based on learning, and reaffirms the importance of climate concepts taught in the classroom as well as a student's connection to those concepts. 31 As

27 Harlen. “ASE guide to primary science education”
28 Turkoglu. “Opinions of Preschool Teachers and Pre-Service Teachers on Environmental Education and Environmental Awareness for Sustainable Development in the Preschool Period”
29 Kelly. “Rethinking the elementary science methods course: a case for content, pedagogy, and informal science education” 759.
30 Jimenez and Moorhead. “‘Don’t Say It’s Going to Be Okay’: How International Educators Embrace Transformative Education to Support their Students Navigating Our Global Climate Emergency” 5-6.
31 Ibid. 6.
well as school culture, budget cuts and funding constraints are viewed by faculty as the leading barrier to science education and a disconnect between science educators and the science community. Both factors can compound hesitation towards climate change education and opportunities to change school-wide attitudes are essential for a climate-oriented science classroom.

Connection to communities outside of the classroom stimulates environmental awareness and understanding of climate systems. In order to execute foundational science skills, students should be able to connect concepts with the real world. Climate education should exist as transmissive education, meaning that educators should introduce climate knowledge in a social context that resides beyond the boundaries of the school. As students are introduced to environmental and climate concepts in a real-world context, they will develop more positive environmental attitudes and can retain climate concepts more readily than those instructed in a traditional learning group. Rather than encountering climate concepts in a standardized and limited framework, connecting content to community encourages student empowerment and critical thinking, which are important motifs for young learners to associate with climate science learning and thinking.

Knowledge and attitudes are recognized as having considerable effect on the success of climate action and can be shaped using climate curriculum. The delivery of this information to students can have different results in developing student attitudes about the climate and their

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32 Colston and Ivey. “(un)Doing the Next Generation Science Standards: .783
33 Dalida, Malto, and Lagunzad. “Enhancing Students’ Environmental Knowledge and Attitudes Through Community-based Learning” 205.
34 Jimenez and Moorhead. 5-6.
35 Howard-Jones, Sands, Dillon, and Fenton-Jones. 1673.
36 Leicht, Heiss, and Byum. “Issues and trends in Education for Sustainable Development” 34.
37 Karpudewan, Rother, and Abdullah. “Enhancing Primary School Students’ Knowledge about Global Warming and Environmental Attitude Using Climate Change Activities. 34
relationship to it. Giving students access to information about climate change and other fundamental science concepts through inquiry and action-based lessons improves understanding but can also foster negative feelings about climate change.\textsuperscript{38} After learning of the consequences of climate change, students may experience an empathetic burnout, and gradually feel disconnected and unwilling to act on behalf of the climate. Although compassion fatigue is less likely to occur in elementary students\textsuperscript{39}, the development of sustainable positive feelings is critical to ensure early education of climate will result in positive attitudes towards climate action. The concept of comprehensive hope can be utilized to frame action taken in class or in the community as a method to reinforce that regardless of age, students are capable of enacting measurable change.

\textbf{Next Generation Science Standards}

There is already widespread support from educators to incorporate climate change and other climate-related curriculum into science instruction. In 2018, the National Science Teachers Association released a statement calling for evidence-based instruction on climate change at all levels, stating, “a large body of foundational knowledge exists regarding climate science that is agreed on by the scientific community and should be included in science education at all levels” \textsuperscript{40}. The Next Generation Science Standards (NGSS) represent the most current and pedagogically sound method for STEM instruction on a K-12 level and are the most explicit standards on climate instruction and information. Released in 2013, NGSS is utilized in instruction of roughly 36% of American students and is designed to promote interdisciplinary science learning.\textsuperscript{41} Next

\textsuperscript{38} Jimenez and Moorhead.
\textsuperscript{39} Kelly. “Rethinking the elementary science methods course: a case for content, pedagogy, and informal science education” 759
\textsuperscript{40} National Science Teachers Association. “The Teaching of Climate Science”. 1
Generation Science Standards are instructed based on the 5-E model, which allows teachers to plan inquiry-based lessons in which students are actively engaged in drawing on their preconceptions to develop a deep understanding of content.

The design of the Next Generation Science Standards is intended to have science and engineering instruction mirror the current methodologies of approach for modern scientists and engineers.42 Next Generation Science Standards attempt to deliver science material through the lens of three separate matrices: scientific and engineering practices, which are a series of practices used in science and engineering, disciplinary core ideas, central concepts used in different science and engineering disciplines, and cross cutting concepts, which represent connections between the different domains of science43-44. These central concepts are described with varying levels of complexity depending on the intended grade band and intended subject per module. While the Disciplinary Core Ideas only have relevance depending on unit subject, the Science and Engineering Practices and Crosscutting Concepts can be applied to any unit.

<table>
<thead>
<tr>
<th>Science and Engineering Practices45</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asking Questions and Defining Problems</td>
</tr>
<tr>
<td>Developing and Using Models</td>
</tr>
</tbody>
</table>

44 Wang and Liu. 1287.
| Planning and Carrying Out Investigations | Scientists and engineers plan and carry out investigations in the field or laboratory, working collaboratively as well as individually. Their investigations are systematic and require clarifying what counts as data and identifying variables or parameters. Engineering investigations identify the effectiveness, efficiency, and durability of designs under different conditions. |
| Analyzing and Interpreting Data | Scientific investigations produce data that must be analyzed in order to derive meaning. Because data patterns and trends are not always obvious, scientists use a range of tools to identify the significant features and patterns in the data. Scientists identify sources of error in the investigations and calculate the degree of certainty in the results. Engineering investigations include analysis of data collected in the tests of designs. This allows comparison of different solutions and determines how well each meets specific design criteria—that is, which design best solves the problem within given constraints. |
| Using Mathematics and Computational Thinking | In both science and engineering, mathematics and computation are fundamental tools for representing physical variables and their relationships. They are used for a range of tasks such as constructing simulations; solving equations exactly or approximately; and recognizing, expressing, and applying quantitative relationships. Mathematical and computational approaches enable scientists and engineers to predict the behavior of systems and test the validity of such predictions. |
| Constructing Explanations and Designing Solutions | The end-products of science are explanations, and the end products of engineering are solutions. The goal of science is the construction of theories that provide explanatory accounts of the world. A theory becomes accepted when it has multiple lines of empirical evidence and greater explanatory power of phenomena than previous theories. The goal of engineering design is to find a systematic solution to problems that is based on scientific knowledge and models of the material world. |
| Engaging in Argument form Evidence | Argumentation is the process by which evidence-based conclusions and solutions are reached. In science and engineering, reasoning and argument based on evidence are essential to identifying the best explanation for a natural phenomenon or the best solution to a design problem. Scientists and engineers use argumentation to listen to, compare, and evaluate competing ideas and methods based on merits. Scientists and engineers engage in argumentation when investigating a phenomenon, testing a design solution, resolving questions about measurements, building data models, and using e |
| Obtaining, Evaluating, and Communicating Information | Scientists and engineers must be able to communicate clearly and persuasively the ideas and methods they generate. Critiquing and communicating ideas individually and in groups is a critical professional activity. Communicating information and ideas can be done in multiple ways: using tables, diagrams, graphs, models, and equations as well as orally, in writing, and through extended discussions. |

Crosscutting Concepts

<table>
<thead>
<tr>
<th>Patterns</th>
<th>Observed patterns in nature guide organization and classification and prompt questions about relationships and causes underlying them.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cause and Effect</td>
<td>Events have causes, sometimes simple, sometimes multifaceted. Deciphering causal relationships, and the mechanisms by which they are mediated, is a major activity of science and engineering.</td>
</tr>
<tr>
<td>Scale, Proportion, and Quantity</td>
<td>In considering phenomena, it is critical to recognize what is relevant at different size, time, and energy scales, and to recognize proportional relationships between different quantities as scales change.</td>
</tr>
<tr>
<td>Systems and System Modeling</td>
<td>A system is an organized group of related objects or components; models can be used for understanding and predicting the behavior of systems.</td>
</tr>
<tr>
<td>Energy and Matter</td>
<td>Tracking energy and matter flows, into, out of, and within systems helps one understand their system’s behavior.</td>
</tr>
<tr>
<td>Structure and Function</td>
<td>The way an object is shaped or structured determines many of its properties and functions.</td>
</tr>
<tr>
<td>Stability and Change</td>
<td>For both designed and natural systems, conditions that affect stability and factors that control rates of change are critical elements to consider and understand.</td>
</tr>
</tbody>
</table>

Above: A review of the Next Generation Science Standards Science and Engineering Practices and Crosscutting Concepts. These standards remain the same regardless of content of instruction.

Although the term “climate change” is explicitly stated in middle and high school standards, NGSS omits the phrasing in elementary Disciplinary Core. Instead, elementary standards separate the several systems and mechanisms involved in climate change into separate standards as a means of providing foundational knowledge of Earth’s systems without human influence as preparation to learn about climate change. The relationship between humans and earth systems is consistently stated throughout K-12 standards. NGSS performance standards are designed to build upon each other so elementary standards will have the broadest context and will gradually narrow into more specific objectives.47 For elementary students, the *Human impacts on Earth Systems* standards states for K-2 that, “Things people do can affect the environment, but they can make choices to reduce their impacts” and for 3-5 states, “Societal activities have had

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47 Next Generation Science Standards. “Get to Know the Standards”.
major effects on the land, ocean, atmosphere, and even outer space. Societal activities can also help protect Earth’s resources and environments.”48 The broad strokes of the elementary earth science standards create room for the introduction of climate science concepts without needing the explicit inclusion of climate language that may be difficult to generate broad support for.

Discussion

Based on existing literature, elementary climate change education can be a successful tool for developing advocacy in children. Although climate change concepts can be intimidating for elementary science educators, effective professional development and an encouraging school environment can facilitate the community-based, hands-on learning that is shown to be most effective in early climate education. At this point, many science teachers must make the decision to incorporate climate change concepts into their curriculum without instruction or guidance from accepted learning standards. The Next Generation Science Standards are the most current set of science standards that implement concepts of inquiry and application on a K-12 scale. Although the elementary Earth Science standards omit climate change concepts, the introductory concepts concerning Earth systems are broad enough to allow instruction of climate change by instructors who wish to incorporate it into their instruction. For those teachers who wish to develop climate change concepts into existing curriculum, prepared curriculum with guidance on instruction is important.

Below is a sample curriculum for instruction on the water cycle and climate change. The curriculum proposal follows the 5E instructional model which encourages learning new ideas as well as building on previous understanding through an engagement, exploration, explanation,
elaboration, and evaluation phase. The engagement phase allows students to experience an
example of a concept or a problem that needs to be solved, and thoughts or predictions are
generated based on the experience and the students’ prior knowledge.\textsuperscript{49} The exploration phase
brings students to engage with the concept or problem and self-guided discovery is encouraged.\textsuperscript{50}
The explanation phase takes the refined thoughts and understanding of concepts gathered in the
exploration phase to discussion, and the elaboration portion allows students to apply newly gained
information to different modes of application.\textsuperscript{51} The evaluation portion is used to check
understanding and to identify gaps in comprehension to be able to better clarify.

This unit is based on an existing unit intended for instruction for second and third graders.
The unit begins with a discussion of evaporation, then goes to condensation, and finally concludes
with a discussion of the water cycle. Using existing NGSS standards, these concepts can be
expanded to include several climate change concepts, including how using resources affects the
environment, how it impacts climate change, and how climate change in turn can affect the amount
of water available as a resource for humans to use. The final lessons are using action-based
planning for climate change action in a format that can be adapted to different locations in the
United States to establish community connection.

\textsuperscript{49} Wang and Liu. Engaging K-8 Preservice Teachers.
\textsuperscript{50} Ibid.
\textsuperscript{51} Ibid.
Curriculum Proposal

Water, Water, Everywhere Unit Plan

Intended Grade Band: 2-5

Unit Goal: In this unit, students will learn about the processes of the water cycle as well as how climate change influences how much water is available for human use. To conclude, students will create climate action plans to try and improve the water availability for humans in their community.

<table>
<thead>
<tr>
<th>NGSS Unit Performance Standards:</th>
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<tbody>
<tr>
<td>2-ESS2-3 Earth’s Systems: Obtain information to identify where water is found on Earth and that it can be solid or liquid.</td>
</tr>
<tr>
<td>3-ESS3-1 Earth and Human Activity: Make a claim about the merit of a design solution that reduces the impacts of a weather-related hazard.</td>
</tr>
<tr>
<td>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.</td>
</tr>
<tr>
<td>4-ESS3-1 Earth and Human Activity: Obtain and combine information to describe that energy and fuels are derived from natural resources and their uses affect the environment.</td>
</tr>
<tr>
<td>4-ESS3-2 Earth and Human Activity: Generate and compare multiple solutions to reduce the impacts of natural Earth processes on humans.</td>
</tr>
<tr>
<td>5-ESS2-1 Earth’s Systems: Develop a model using an example to describe ways the geosphere, biosphere, hydrosphere, and/or atmosphere interact.</td>
</tr>
<tr>
<td>5-ESS2-2 Earth's Systems: Describe and graph the amounts and percentages of water and fresh water in various reservoirs to provide evidence about the distribution of water on Earth.</td>
</tr>
<tr>
<td>5-ESS2-2. Earth’s Systems: Describe and graph the amounts of saltwater and fresh water in various reservoirs to provide evidence about the distribution of water on Earth.</td>
</tr>
</tbody>
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<table>
<thead>
<tr>
<th>Lesson 1: Water Filtration</th>
<th>Time Frame: 70-90 min</th>
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</thead>
<tbody>
<tr>
<td>Brief Lesson Description:</td>
<td>Students will work in groups to try to filter out certain contaminants in water using household materials.</td>
</tr>
<tr>
<td>Learning Objectives:</td>
<td>• Students will learn that many human-made contaminants in water cannot be easily filtered.</td>
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<td></td>
<td>• Students will design multi-layered water filters capable of filtering small and large particles.</td>
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<tr>
<td></td>
<td>• Students will be able to describe the need for water filters and to protect water sources.</td>
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<tr>
<td></td>
<td>• Students will use teamwork to solve a problem.</td>
</tr>
</tbody>
</table>
Science and Engineering Practices
1. Asking questions and defining problems
2. Developing and using models
3. Constructing explanations and designing solutions
4. Obtaining, evaluating, and communicating information

Disciplinary Core Ideas:
- 3-ESS3-1
- 3-5-ETS-1
- 4-ESS3-1

Crosscutting Concepts:
1. Patterns
2. Cause and effects
3. Scale, proportion, and quantity
4. Structure and function

Possible Preconceptions/Misconceptions:
- If water is clear and has no objects mixed in it, it is considered clean and safe for use.
- Most water contaminants can be filtered out, making the water reusable.
- Water is fully available for use and there are only limited amounts that are not safe for use.

LESSON PLAN – 5-E Model

ENGAGE: Opening Activity – Access Prior Learning / Stimulate Interest / Generate Questions:
Begin with discussion on how humans use water:
- How do you use water on a daily basis?
- Once this water is used, can we use it again?
- Where does the used water go?

EXPLORE:
Lesson Description:
After opening discussion, students will be instructed to plan and construct a water filter using available materials to filter three types of contaminated water. In order, students will filter 1) water with dirt, and 2) water with cornstarch, and 3) water with food dye. Groups will plan a design with materials and have three attempts to successfully filter out each contaminant. Once successful, the group can move onto the next contaminant. The water with dirt and water with cornstarch can be tested by eye and the water with food dye will be tested by eye. Successful filters often have many layers of several different materials.

Materials Suggested:
- Handout 1
- 2L Soda bottle cut in half
- Coffee filters
- Sand
- Cotton balls
- Tea bags
- Cotton pads
- Corn kernels
- Small rocks
- Large rocks
- Marbles

EXPLAIN:
Concepts Explained:
- Much of the water we use becomes polluted, and it is difficult to clean.
- A successful filter has several layers for the water to pass through.

Vocabulary Defined:
- Water filter: A device that removes something unwanted from a liquid or gas that is passed through it.
- Contaminant: Something that makes a place or a substance, such as water, air, or food, unfit for use; something harmful or unwanted that makes a place or substance dangerous, dirty, or impure.
- Particulate: A small fragment that is present in a water supply.

EVALUATE:
Students will document all ideas and materials used in the related worksheet for this activity. Encourage students to use as much detail as possible when documenting group ideas. If there is time, show examples of successful filters: for dirt and cornstarch, a simple layer of coffee filters will do, for water with food dye, a number of combinations may be successful if there is a variety of layers.

Lesson 2: Global Water Composition

Time Frame: 35-50 min

Brief Lesson Description: Students will describe existing ideas on global water distribution between freshwater and saltwater and will then learn about where the water is in the world.

Specific Learning Outcomes:
Students will understand that only 3% of available water on earth is freshwater.
Students will discover that water is found in 5 main categories on Earth: Rivers/Lakes, Atmosphere, Groundwater, Ice, and Oceans.
Students will learn only 1.75% of freshwater is available for human use.

Prior Student Knowledge:
Freshwater and saltwater are both available for human use, but humans can use freshwater for many more things.

Science and Engineering Practices
1. Asking questions and defining problems
2. Developing and using models
3. Analyzing and interpreting data
4. Using mathematics and computational thinking
5. Obtaining, evaluating, and communicating information

Disciplinary Core Ideas:
- 2-ESS2-3
- 5-ESS2-2

Crosscutting Concepts:
1. Scale, proportion, and quantity
2. Systems and system models

Possible Preconceptions/Misconceptions:
Available freshwater is available in even proportion between the four major sources of freshwater
The amount of freshwater and saltwater available globally is equal

ENGAGE:
Begin with discussion from last lesson:
- Why did our project with water filters show why conserving water is important?
- How much water is available to us for use? Where do we find this water?
Collect ideas on where we find water. Fill in gaps by identifying 5 major sources (Oceans, Lakes/Rivers, Ice, Atmosphere, and Groundwater)

EXPLORE:
In small groups, ask students to group together what percent of the world’s water is available in each source by dividing the water in the largest beaker among the five labeled as each main water source. Students can measure based on measurements on beaker or can use the scale to confirm their thoughts are accurately reflected in the water distribution. Collect data from each group and discuss with the class. Each group may have very different distributions. Reveal true distribution:
- Oceans: 96.5%
- Lakes/Rivers: 0.013%
- Atmosphere: 0.001%
- Groundwater: 1.7%
- Ice: 1.7%

Materials Suggested:
- 1000 ml of water per group
- Scale
- 1 large beaker
- 5 small beakers labeled as each water source
- Paper to record groups estimated distribution
- Teacher set of cups with correct distribution

EXPLAIN:
Concepts Explained:
- Only 1.75% of water on Earth is freshwater available for human use.
- The majority of freshwater is not easily available for human use - water in the atmosphere and in ice is not in a state of matter that can be accessed.

Vocabulary Defined:
- Atmosphere: The layer of gas that surrounds Earth.
- Groundwater: Water that is stored underground in porous rocks.
- States of matter: Solid, liquid, and gas; used to describe the different states that all matter exists in.

EVALUATE:
Teachers can choose to document student’s initial predictions for water distributions to note preconceptions and misconceptions. Lesson finishes with the distribution reveal and showing distribution with class model.

<table>
<thead>
<tr>
<th>Lesson 3: Evaporation</th>
<th>Time Frame: 70-90 min</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Brief Lesson Description:</strong> Students will set up an experiment to determine what characteristics of water bodies lead to higher rates of evaporation.</td>
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</table>

**Specific Learning Outcomes:**
- Students will collaborate as a team to design an experiment.
- Students will practice the Scientific process by designing several fair tests with independent and dependent variables.
- Students will learn that larger surface areas, warmer temperatures, and more shallow water bodies will experience high rates of evaporation.

**Prior Student Knowledge:**
- A fair experiment requires several independent variables and one dependent variable.
- A fair experiment can be replicated multiple times to have the same result.

**Science and Engineering Practices**
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**Disciplinary Core Ideas:**
- 5-ESS2-1

**Crosscutting Concepts:**
1. Patterns
2. Cause and effects
3. Scale, proportion, and quantity
4. Systems and system models
5. Energy and matter
6. Structure and function
7. Stability and change

**Possible Preconceptions/Misconceptions:**
- Evaporation only occurs when water is boiling.
- Steam is the only type of evaporation.
- Evaporation is always visible.
- Water, no matter the exterior conditions, will evaporate at the same rate.

**LESSON PLAN – 5-E Model**

**ENGAGE:**
Begin with discussion about what affects available freshwater. Based on previous activities, students know that freshwater is very limited, but what natural and human-influenced systems affect water? Where do we get water? Where does that water come from?
### EXPLORE:
After students identify that most water is found in lakes and rivers, the teacher will suggest recreating some of these conditions to see how water changes with only natural effects. As a class, students will establish a series of fair tests using several different containers to hold water. Ideal comparisons are:
- Same container, different temperatures (temperature)
- Shallow container and deep container (depth)
- Wide container and narrow container (surface area)

Once the setup of the experiment is established, students will add the same amount of water to the containers chosen and the containers will be left overnight or until the next class. The following class reveals the results of the experiment. Students will document the difference in volume of the water in the different containers. How is this possible? Teacher will reveal that the process of evaporation is occurring with all the water and introduce the concept of heat, surface area, and depth as an influence of evaporation.

### Materials Suggested:
- Various containers to hold water (beakers, buckets, cups, etc.)
- Water
- Material to add labels
- Access to a cold environment
- Access to a warm environment

### EXPLAIN:

**Concepts Explained:**
- Several natural conditions affect the rate of evaporation of water. Conditions like warmer temperatures, larger surface areas, and more shallow containers will increase evaporation, while colder temperatures, smaller surface areas, and deeper containers will decrease evaporation.
- Warmer temperatures increase the amount of heat in a body of water, thereby accelerating the process of evaporation.
- Larger surface areas and more shallow containers allow more water molecules to be exposed to the heat in the air, thereby accelerating the process of evaporation.
- Evaporation occurs at any point above a freezing temperature (0 degrees C). Even though it is not visible, water is constantly evaporating into its liquid form, water vapor, when exposed to any amount of heat.
- LIQUID + HEAT → GAS (rule) or WATER + HEAT → WATER VAPOR (example)

**Vocabulary Defined:**
- Evaporation: The process of turning liquid water into water vapor in the presence of heat.
- Water vapor: The gaseous state of water.
- Freezing point: The temperature point that causes a liquid to turn into a solid. For water, it is 0 degrees C.
- Boiling point: The temperature point that causes a liquid to boil and turn into a gas. For water, it is 100 degrees C.

### EVALUATE:
After explaining evaporation, ask students to write a conclusion for the results of the experiment. The conclusion should state the evidence and explain why certain bodies of water evaporated more quickly than others.

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### Lesson 4: Condensation

**Time Frame:** 35-45 min

**Brief Lesson Description:** Students will observe water condensing on cold surfaces to learn about the condensation part of the water cycle.

**Specific Learning Outcomes:**
- Students will make conclusions based on observations made in a controlled setting.
Students will learn that water vapor requires a cold surface to condensate into liquid water.

Students will learn that there is water vapor in all areas of the atmosphere, not just at higher elevations.

**Prior Student Knowledge:**

- Water vapor is released into the atmosphere through evaporation.

**Science and Engineering Practices**

1. Developing and using models
2. Planning and carrying out investigations
3. Engaging in argument from evidence
4. Obtaining, evaluating, and communicating information

**Disciplinary Core Ideas:**

- 5-ESS2-1

**Crosscutting Concepts:**

1. Cause and effects
2. Systems and system models
3. Energy and matter
4. Structure and function
5. Stability and change

**Possible Preconceptions/Misconceptions:**

- Condensation on the outside of a container comes from the water inside the container.
- Condensation is when air turns into a liquid.

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**LESSON PLAN – 5-E Model**

**ENGAGE:**

Students will begin with a review of evaporation. Prompt discussion by asking, “What happens to the water that evaporates?” The class will watch what happens to evaporated water by observing a metal cup filled with ice, water, and food dye.

**EXPLORE:**

As time goes on during observation, students will notice water forming on the outside of the cup. Ask students where the water comes from. Some may say from inside the cup. Correct this by pointing out that the water on the outside of the cup is not the same as the water inside (because of the food dye). Begin explaining the concept of condensation and the formula for why this occurs.

**EXPLAIN:**

**Concepts Explained:**

- The water vapor that condenses on a cold surface comes from the water vapor in the atmosphere, not nearby sources of liquid water.
- Although the water vapor is not visible, it is in the atmosphere and will become liquid water if it can cling to a cold surface.
- \( \text{GAS} + \text{COLD SURFACE} \rightarrow \text{LIQUID} \) (rule) or \( \text{WATER VAPOR} + \text{COLD SURFACE} \rightarrow \text{WATER} \) (example)

**Vocabulary Defined:**

- Condensation: The process of turning water vapor into liquid water in the presence of a cold surface.
- Water vapor: The gaseous state of water.
- Atmosphere: The layer of gas that surrounds Earth; the air we breathe.

**EVALUATE:**

Ask students to write down an explanation of condensation in their own words. This will catch any misunderstandings before connecting everything in the water cycle.

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**Lesson 5: Water Cycle**

**Time Frame:** 35-50 minutes
Brief Lesson Description: Students will connect what they have learned about the water cycle to understand the water cycle and the processes of evaporation, condensation, precipitation, and collection.

Specific Learning Outcomes:
- Students will be able to identify the four parts of the water cycle and how water changes from one part to the next.
- Students will learn that precipitation appears in 4 forms: rain, snow, sleet, and hail.
- Students will learn that collection is how precipitation is gathered in water bodies as well as underground aquifers.

Prior Student Knowledge:
- Information from Lesson 3 and Lesson 4 are essential.

Science and Engineering Practices
1. Developing and using models
2. Constructing explanations and designing solutions
3. Obtaining, evaluating, and communicating information

Disciplinary Core Ideas:
- 5-ESS2-1

Crosscutting Concepts:
1. Cause and effects
2. Scale, proportion, and quantity
3. Energy and matter
4. Stability and change

Possible Preconceptions/Misconceptions:
- The water cycle involves freezing and melting of water.
- Water only evaporates from the ocean or lakes.
- Precipitation only includes rain and snow.

LESSON PLAN – 5-E Model

ENGAGE:
Review the processes and formulas of evaporation and condensation. The class witnessed condensation because conditions were created to facilitate that, but how does this happen when no humans are around?

EXPLORE:
Lead students through a diagram of the water cycle. It is typically best to begin with evaporation of a puddle of water or a similar body of water. As it evaporates, it goes into the air. Students may mention clouds at this point and rainfall. Ask how the liquid water gets into the air as rain. This is the connection point: water vapor will connect to microscopic solids of dirt, dust, or pollutants in the cold air and will condense to become liquid water.

Demonstrate how the cloud forms by cooing the inside of the bottle, adding warm water and a burning match. The particles from the match will aerate and the evaporated water will cling together, making a cloud. As the clouds become a larger collection of liquid water, precipitation will occur. As precipitation falls as rain, snow, sleet, or hail, it will then collect in larger bodies or water or underground in a process called collection.

Materials Suggested:
- 2L soda bottles cut 1/3 from the top
- Matches
- Ice
- Warm water
### EXPLAIN:

**Concepts Explained:**
- The water cycle moves and changes water throughout the environment and atmosphere.
- Precipitation can occur in the form of rain, snow, sleet, or hail, depending on atmospheric conditions.
- Water will evaporate from all forms of water found in nature, including oceans.

**Vocabulary Defined:**
- Water cycle: The movement of water on and around Earth through different states of matter.
- Precipitation: The release of water from the sky, it can be liquid or solid, for example, rain, sleet, hail, and snow.
- Collection: Liquid water gathering into oceans, rivers, lakes, and other bodies of water from precipitation.

### EVALUATE:

After the demonstration of the cloud formation, students will be asked to explain how we were able to recreate the formation of a cloud in the classroom. As an additional task, the instructor may also ask students to explain why condensation is important for the water cycle in the natural world and how it provides water for humans to use.

### Lesson 6: River Flow Simulation

**Time Frame:** 70-90 minutes

**Brief Lesson Description:** Students will apply the information gained about the water cycle to then explore how human activity influences the amount of water available for use.

**Specific Learning Outcomes:**
- Students will work together to determine how water is used to meet the demands of human development.
- Students will learn how different human activities affect the quality and supply of water in an area.
- Students will be introduced to the concept of climate change and how it affects the supply of water.

**Prior Student Knowledge:**
- The water cycle influences how much water is naturally available in an area.

**Science and Engineering Practices**
1. Asking questions and defining problems
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3. Constructing explanations and designing solutions
4. Obtaining, evaluating, and communicating information

**Disciplinary Core Ideas:**

- 3-5-ETS-1
- 4-ESS3-1
- 5-ESS2-2

**Crosscutting Concepts:**
1. Cause and effects
2. Scale, proportion, and quantity
3. Systems and system models
4. Structure and function
5. Stability and change

**Possible Preconceptions/Misconceptions:**
- Climate change is a part of a natural cycle.
- Climate change is related to temperature and not always water.

### LESSON PLAN – 5-E Model

**ENGAGE:**
Review with class how nature influence the amount of water in an area (precipitation, condensation, evaporation, and collection). How do humans affect the amount of water in an area? Take students suggestions, but ideally these ideas will be mentioned:
- Reservoirs
- Groundwater
- Tributaries
- Water use in cities and homes
- Water in factories

**EXPLORE:**
Students will then complete an activity that tests how water demand changes as an area becomes more developed. The goal is to construct a river formation with clay on the board that will bring water to all the pieces that need it. Once students are successful at one level, they will then have to redesign to bring the water to more pieces. The order will be:
- Two small towns
- Switch small for big town, small town
- Add reservoir
- Add factory
- Reduce amount of water by half (climate change)

By the end of the activity, students will only be able to use half of the amount of water available in previous levels. This is to introduce the concept of climate change and its relationship to water.

**EXPLAIN:**
**Concepts Explained:**
- Climate change is exacerbated by human activity.
- As an area of land develops, more water is required, and more water is at risk of being contaminated.
- Humans must act wisely to have enough water to use.

**Vocabulary Defined:**
- Water scarcity: A condition where the amount of water needed is larger than the amount of water available.
- Climate change: a change in the average conditions - such as temperature and rainfall - in a region over a long period of time

**EVALUATE:**
Discuss challenges in the simulation. Who was successful and to what extent? Begin discussing the climate change level. Why was the water taken away? How does the amount of water relate to climate change? Use this conversation to see activity takeaways and conceptions of climate change before the next lesson.

<table>
<thead>
<tr>
<th>Lesson 7: Climate Change</th>
<th>Time Frame: 35-50 min</th>
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<tbody>
<tr>
<td><strong>Brief Lesson Description:</strong> Students will learn about the implications of climate change to the atmosphere and the water cycle.</td>
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</tbody>
</table>

**Specific Learning Outcomes:**
• Students will learn that climate change occurs naturally over long periods of time, but human activity has sped up the process.
• Students will learn that climate change influences the amount of rain and the average temperature of different regions – it may increase or decrease.
• Students will understand how the water cycle is influenced by climate change.

Prior Student Knowledge:
• The amount of evaporation depends on the heat in the water and the air.
• Water vapor is found in the atmosphere.

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Disciplinary Core Ideas:
• 2-ESS2-3
• 4-ESS3-1

Crosscutting Concepts:
1. Cause and effects
2. Systems and system models
3. Energy and matter
4. Structure and function
5. Stability and change

Possible Preconceptions/Misconceptions:
• Climate change happens because of the sun’s temperature.
• The climate has always changed naturally.
• If it is cold outside, then there is no global warming.
• Human activity does not influence the amount of climate change occurring.

<table>
<thead>
<tr>
<th>LESSON PLAN – 5-E Model</th>
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<tbody>
<tr>
<td>ENGAGE:</td>
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<tr>
<td>Begin class with a discussion about what happened during the river simulation. Why did the water decrease so much at the end of class? The teacher should ask about what students already know about climate change. Begin a discussion with the causes of global warming – the emission of greenhouse gases and the atmosphere trapping heat because of the greenhouse gases.</td>
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<tr>
<td>EXPLORE:</td>
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<tr>
<td>This lesson is the most content heavy of the unit. The concepts must be described without bias so the next activity can be led by student inquiry and production of ideas. Students can better comprehend presence of greenhouse gases by comparing the warmth of blankets or hats – the thicker and denser the material, the better at retaining warmth it will be. Once the greenhouse gas effect is explained, the teacher will talk about the effects of climate change on the water cycle.</td>
</tr>
<tr>
<td>Materials Suggested:</td>
</tr>
<tr>
<td>• A variety of hats or blankets with different thicknesses – cotton, polyester, wool, etc.</td>
</tr>
<tr>
<td>• Supplemental videos or graphics to explain greenhouse effect and climate change</td>
</tr>
<tr>
<td>EXPLAIN:</td>
</tr>
<tr>
<td>Concepts Explained:</td>
</tr>
<tr>
<td>• The greenhouse effect causes heat to be trapped in the atmosphere, warming the planet.</td>
</tr>
<tr>
<td>• Climate change influences the amount of rain and the average temperature of different regions – it may increase or decrease.</td>
</tr>
<tr>
<td>• Climate change decreases the amount of water available for use because of increases in evaporation rates due to higher temperatures.</td>
</tr>
<tr>
<td>Vocabulary Defined:</td>
</tr>
</tbody>
</table>
• Climate change: The long-term changes in global temperatures and other characteristics of the atmosphere
• Greenhouse gas: Gases in the Earth’s atmosphere that allow heat to enter through the atmosphere but keeps it from escaping.
• Drought: A lack or insufficient amount of rain for an extended period is called drought
• Water scarcity: A limited amount of freshwater that is not enough to meet the human and environmental needs of a given area.

EVALUATE:
At the end of the discussion of climate change, have a class discussion for action on how to limit the effects of climate change. Evaluate if students are giving reasonable answers based on the information given during class.

Lesson 8: Water Scarcity Case Study

Brief Lesson Description: Students will work in groups to develop action-based policy that can help reduce the effects of climate change in a local area.

Learning Objectives:
• Students will learn that individual and collective action both help combat climate change.
• Students will design promotional materials to help convince peers to act on climate change.
• Students will be able to describe the need to protect water sources and act to minimize climate change.
• Students will use teamwork to solve a problem.

Prior Student Knowledge:
• Students may have some knowledge about renewable energy and the ways humans are already trying to fix climate change, but this may vary based on previous experience.

Science and Engineering Practices
1. Planning and carrying out investigations
2. Constructing explanations and designing solutions
3. Engaging in argument from evidence
4. Obtaining, evaluating, and communicating information

Disciplinary Core Ideas:
• 4-ESS3-2

Crosscutting Concepts:
1. Patterns
2. Cause and effects
3. Scale, proportion, and quantity
4. Systems and system models
5. Energy and matter
6. Structure and function
7. Stability and change

Possible Preconceptions/Misconceptions:
• Individual action is mostly responsible for the climate problem.

LESSON PLAN – 5-E Model

ENGAGE:
Based on the information given last class, students will work in groups to develop an action plan for how to fix a water scarcity problem in the area. Example: The Colorado River Basin is threatened by severe drought due to climate change. Classes in the southwest could use this water body for their studies.

It is recommended to look at current water use for the water body to start learning about how the water is used now. It may be a division of hydroelectric, industrial, agricultural, and so on. It is important to define these terms depending on what the local water body is used for.

EXPLORE:
As students research about their local water body and how water is used, they will develop some action plans for how to fix it. Some plans may include:

Materials Suggested:
• iPads for research
• Variety of materials for creating action plan
- Decreasing the amount of water used for energy and using wind and solar power instead.
- Using crops that need less water.
- Decreasing the amount of water used in homes.

**EXPLAIN:**

**Concepts Explained:**
- Individuals and organizations can help solve climate change.
- Climate change is affecting all parts of the world, including the student’s region.
- Students can develop ideas to help fix climate change.

**Vocabulary Defined:**
- Climate action: Changing habits or ways of doing things to fix climate change.
- Mitigation: Avoiding or reducing greenhouse gas emissions.
- Adaptation: Changing the way we live to better prepare for the effects of climate change.

**EVALUATE:**
Students will document all ideas on a final project that they will use to explain their action plan to the class.
References


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