CREATING A CLASSROOM THAT FOCUSES ON STUDENT SCIENTIFIC LITERACY THROUGH THE SCOPE OF NEXT GENERATION SCIENCE STANDARDS' CROSSCUTTING CONCEPTS

by

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ABSTRACT

The purpose of this paper is to provide teachers with lessons and tools to strengthen middle school students' scientific literacy. Students' reading comprehension skills are at an all-time low which has created hurdles when it comes to understanding science. The lessons in this paper contain tools that utilize Next Generation Science Standards, crosscutting concepts to strengthen reading comprehension and data analysis through the lens of science. Crosscutting concepts are tools used to make connections between varying science concepts to form a better understanding of the world and science. These concepts involve patterns, cause and effect, systems and models, structure and function, stability and change, energy and matter, and scale, proportion and quantity. Each lesson focuses on making one or two of these connections. When students use these lessons to make connections, their understanding of science and phenomena strengthen. When students understand science and the world, they are better equipped to make good decisions and become more positive members of society.

CHAPTER ONE

INTRODUCTION & BACKGROUND

Context

Over the past five years I have taught upper elementary and middle school math and science with a fifth class of either health and wellness or religion classes. This past year, I taught two sections of a combined fourth and fifth grade class, seventh grade and eighth grade science. Before this year I had taught sixth, seventh and eighth grade math for four years and fifth grade science for three years. It was my first year teaching the following science classes: a combined class of fourth and fifth graders, seventh grade and eighth grade. The school where I taught is located on one of the seven American Indian Reservations in Montana. All students at my school were American Indian, with a majority being Amskapi Piikuni (Blackfeet). Montana's state constitution reads, "the state recognizes the distinct and unique cultural heritage of American Indians and is committed in its educational goals to the preservation of their cultural integrity" (The Constitution of the State of Montana, Article X, Section 1(2), 1972). Through this, Montana's Office of Public Instruction created Indian Education for All (IEFA). In IEFA, the culture and heritage of American Indians needs to be covered in all subjects including science. A key part to this is that no generalized information is shared with students since all American Indian groups are different and have their own unique culture. The purpose of IEFA is to provide "cultural enrichment, academic engagement, and equitable pedagogy for all students" (Montana Office of Public Instruction, n.d., p. 1).

In Montana, there is an achievement gap between American Indian students and non-American Indian students. Montana's Office of Public Instruction used The Smarter Balance Assessment (SBAC) to document and analyze these proficiency gaps. In 2021, the number of American Indian students who scored proficient or higher in reading was 20% compared to non-American Indian students with 51% of students scoring proficient or higher on the SBAC reading assessment. This gap was also present in SBAC math scores as well with 48% of non-American Indian students proficient and only 18% of American Indian students proficient in math (Kouba & Gopher, 2021). Along with an achievement gap, there has also been a financial hardship among students and families that I have taught. The school I taught at receives Title 1 federal funding because a high number of students are from low-income families (U.S. Department of Education, 2022). Based on the American Community Survey (ACS) 5-year estimates from 2014-2018, the median household income on reservations across the United States was $41,879. For reservations in Montana, the median household income was $32,072 (Holman, 2022).

Most reading and math levels ranged due to a variety of factors. A main factor for not being at grade level was poor attendance. I had many students that had an Individual Education Plan (IEP) and also those who should have had one or been in a specialized education program but were not. Many students were below grade level in reading and math by two to three grades. Due to low reading levels, comprehension of scientific material was not where it should have been.

Students' reading comprehension abilities often were transferred over to science class. Reading comprehension affected a student's ability to read scientific data and figures and their general scientific understanding. The Next Generation Science Standards (NGSS) crosscutting concepts (CCCs) are a tool that can deepen understanding. Crosscutting concepts give students and teachers the tools to make connections across disciplines to enhance their implementation and understanding of core science. They include analyzing patterns, cause and effect, scale, proportion and quantity, systems and system models, energy and matter, structure and function, and stability and change (National Research Council, 2011). When more of a focus on connecting science across disciplinary practices was made, it helped students with their science-based reading comprehension and scientific literacy.

Focus Topic

The purpose of creating lesson materials focusing on NGSS crosscutting concepts was to hone students' science literacy skills, which include understanding data, figures, and graphs, and comprehension of scientific text in middle schoolers. Making students aware of these crosscutting concepts helped improve students' skills needed to increase their own comprehension and ability to pull key ideas and results from data, figures, and scientific literature. The focus was to improve middle school students' scientific literacy including reading and data comprehension through the intentional focus on NGSS crosscutting concepts.

CHAPTER TWO

CONCEPTUAL FRAMEWORK

Scientific Literacy

The ability to understand science is key to contributing fully to life (Fang, 2004). Having the literacy tools needed to think critically about science and other disciplines is how we achieve the goal of turning our students into informed citizens (Douglas, 2014). According to the Victorian State Government Department of Education, scientific literacy is one's ability to understand and then apply concepts of scientific inquiry, phenomena, and process new situations, even ones that are not science-based (Victoria State Government Department of Education, 2021). In one study titled Developing a Measure of Scientific Literacy for Middle School Students, six aspects of scientific literacy were identified (Fives et al., 2014). These were the role of science, scientific thinking and doing, science and society, science media literacy, mathematics in science, and science motivation and beliefs. There is no one definition for scientific literacy, but it includes characteristics of scientific inquiry, content knowledge, and attitudes toward science. Scientific literacy is the ability to participate in scientific thought in all areas including daily life. It is used for general education rather than in education focusing on careers of science and research. Its main function is for someone to be able to understand the natural world and to live with respect to it (Fives et al., 2014). Scientific writing has a high density of information, which often makes scientific literacy difficult for students. Several scholars have suggested that the biggest barrier to the learning of science is the language of science itself (Fang, 2004). Science is so complex, everyday vocabulary cannot properly explain its phenomena so in turn the language used is quite different from that used in everyday life (Fang, 2004).

Another aspect of scientific literacy is the ability to recognize when to ask science-based questions. The importance of asking the right questions is key to understanding the nature of science and inquiry as well as determining what is considered scientific evidence. The next part is the thinking that follows asking questions. Those who are scientifically literate possess the skills to make observations and analyze information to describe, explain, and predict phenomena. With this, scientific literacy also involves the ability to argue for or against data and conclusions using evidence, differentiating between inferences and observations, and identifying patterns (Fives et al., 2014). The Next Generation Science Standards (NGSS) have identified crosscutting concepts (CCCs) that bridge students' abilities to make connections to create and reinforce scientific thinking. The CCCs include patterns; cause and effect; scale, proportion, and quantity; systems and system models; energy and matter; structure and function; and stability and change. CCCs make connections between disciplines to create a developed scientific view of the world (NGSS Framework, 2011).

Reading Comprehension in Elementary and Middle School Students

Reading comprehension can involve a multitude of variables, some of which include making inferences, reading comprehension skills, vocabulary, word reading and prior knowledge of topic. Making inferences is key to scientific understanding as well as to general reading comprehension (McNamara, 2004). Practicing drawing conclusions through inferences increases reading comprehension. The quality of the inference is important. Self-Explanation Reading Training (SERT) teaches students to draw quality inferences. SERT is when one tries to explain to themselves the meaning of text while they are reading. Some strategies for SERT other than making inferences are paraphrasing, comprehension monitoring, elaboration, using logic, and prediction (McNamara, 2004). This program has been used for research with middle school students all the way through undergraduate students. Vocabulary is also essential to reading comprehension because it allows for connections to be made between stored memory and the information in the text (Cromely, 2010).

Understanding Scientific Measurement

The nature of science is built on empirical data (McComas, 2004). Part of scientific literacy is the ability to understand the mathematics behind data to better understand and explain phenomena (Fives et al., 2014). Understanding quantity and the use of measurement are imperative for science education. Scientific measurement describes a phenomenon, which allows one to develop scientific theories and information. Other roles of measurements are to test a hypothesis and to check or create theories. No matter the form, measurements need to be reviewed to draw conclusions about the natural world. The significance of quantitative data is affected by uncertainty or error that correlates with it. For one to use the data to support their claims there must be a reasonable amount of uncertainty; having one number as a measurement is not enough. It is important for scientific measurement and uncertainty to be taught at the elementary and middle school levels. Uncertainty and error can be a result of the quantity being measured, the measuring instrument or the measurer (Munier et al., 2013). The importance of this goes back to the nature of science and how it is a human endeavor. People and the instruments they create are not perfect but can still be used to make sense of the world. In elementary and middle school there are often a great deal of systematic measuring errors due to the students actively making measurements and from the instruments themselves (Munier et al., 2013).

Data and Critical Thinking

Scientists decipher and understand the world using both qualitative and quantitative data. It is important for understanding and analysis to take data in the form of tables and convert them into graphs. When the data is in a graph, it makes it easier to analyze and see patterns. These patterns show the relationships between the variables being studied. According to NGSS, analyzing patterns is a key crosscutting concept which strengthens comprehension and critical thinking (NGSS Framework, 2011). One part of the nature of science is that it is not definite. Scientists understand that when reading scientific research or literature that is based on data and evidence, the data shows the most probable, not the absolute truth. This is also the case for science textbooks, however, students often read them as proven fact. Students need to understand that scientific findings and textbooks display the best explanation we currently have for scientific phenomena. It is important for people, especially students, to understand that one of the main goals of science is to create predictive models in order to better understand the natural world. Analyzing patterns in data through graphs and formulas is essential to achieving this. Often students are required to analyze very clean data, which does not accurately depict science and the world. Clean data is data with little to no error that displays trends with no outlying data points. Open inquiry learning can be used to give students opportunities to avoid clean data and gain experience with more realistic data about the world which will in turn lead to better science literacy skills. These types of lessons and activities force students to explain the validity of their data through scientific argument which is an aspect of the nature of science (McComas, 2004).

When students collect, analyze, and explain their data through argument, they are developing higher-order thinking skills (Bowen & Bartley, 2013). From the data collected, scientists must draw conclusions from the relationships present in their data. This often includes finding averages as well as the dispersion of data, standard deviation. With this, any skill that is required for interpreting data (e.g. mean and standard deviation) is also necessary for developing good data literacy skills (Bowen & Bartley, 2013).

Crosscutting Concepts

Crosscutting concepts were created by the authors of the Next Generation Science Standards with the aim to strengthen student understanding of core ideas of natural science and to build a science-based view of the world. There are seven crosscutting concepts which include identifying patterns; cause and effect; structure and function; scale, proportion and quantity; systems and system models; energy and matter; and stability and change. Identifying patterns helps students organize their observations which will prompt questions about relationships and what things influence them. The next is cause and effect, which can also be described as mechanism and explanation. When cause and effect is studied, it can be used to predict or explain similar phenomena. The third is scale, proportion and quantity which involves the importance of understanding the significance of size and how its changes in scale, proportion and quantity could affect a system. The fourth concept is systems and system models which is connected to all of them. Students should be able to define system specifications and boundaries to create a model of that system. Models are then used by students to test and understand ideas that apply to science and engineering. The fifth crosscutting concept revolves around the understanding of energy and matter in a sense of flow, cycles, and conservation. Students should be able to track energy and matter in, out, and within a system which will allow them to understand the system better through understanding its possibilities and limitations. The next is structure and function. Students can analyze how the shape of an object, organism or system affects the function or job. The final crosscutting concept is stability and change. Students should be able to use this concept to understand that evolution of a system is critical to its stability. When students seek to understand these seven concepts in phenomena, their understanding of how science works strengthens. This is achievable because they all involve fundamental parts of the nature of science (NGSS Appendix G, 2013).

CHAPTER THREE

INSTRUCTIONAL STRATEGIES

The instructional resources in this paper can be used as supplemental lessons to be added to units to provide an additional support and focus on scientific literacy in the realm of reading and data comprehension. Each lesson can be reframed to focus on a variety of NGSS standards and topics while keeping the skeleton focused on crosscutting concepts and scientific literacy. In addition to crosscutting concepts as a focal point of the lessons, the importance of vocabulary is incorporated as well. Vocabulary is incorporated into all lessons and is important in developing scientific literacy skills. The first lesson is to be used at the beginning of a semester where students can begin to think more intently about scientific literacy and what it means to be a scientist. The following four lessons focus on using the specific crosscutting concepts of identifying patterns; cause and effect; structure and function; scale, proportion and quantity; systems and system models; energy and matter; and stability and change (Figure 1). The lessons will provide students with tools to hone scientific literacy skills specifically in reading and data comprehension. The lessons are created so that they can be adapted and reused with different science content and standards. Each lesson follows the 5E lesson plan format. There are different forms of the 5E format and the one used is: engage, explore, explain, evaluate and extend (Figure 2). To allow teachers to track students' progress of understanding scientific literacy and crosscutting concepts, the Scientific Literacy Self-confidence Survey can be used (Appendix A). The survey should be used after lesson one and then at the end of the school year after incorporating the four crosscutting concepts focused lessons. It can also be used more frequently depending on the teacher's preference.

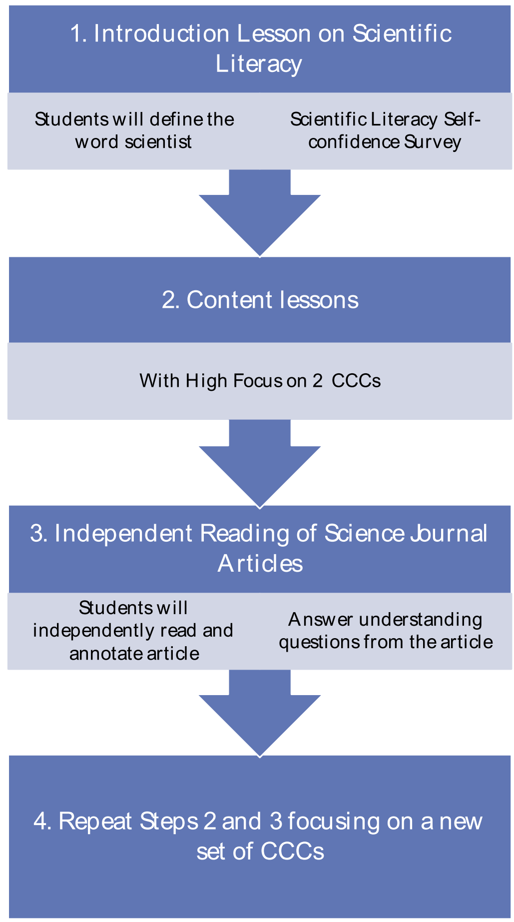

Figure 1: Flow chart explaining the flow of lesson materials.

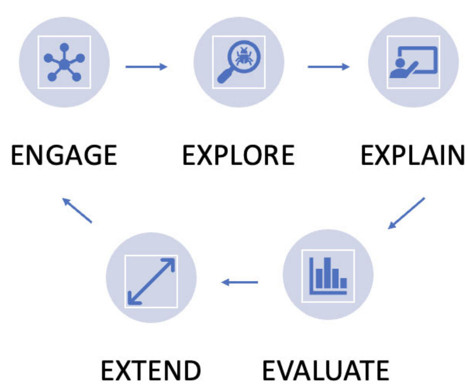

Figure 2: Flowchart of the basic steps of a 5E lesson plan cycle.

Creating Student Awareness of Science

It is important for students to know the difference between literacy and scientific literacy to fully understand scientific literacy. A first step at achieving this is having students determine what a scientist is and, also, more importantly who a scientist could be.

Lesson 1: Defining a Scientist

The Defining a Scientist, 5E lesson is to be done at the beginning of the school year and potentially a second or third time as the year goes on to see students' change in perspectives (Appendix B). The lesson is designed to be taught over two to three days with a goal of creating a definition of the word scientist. Students look at a picture of people representing various professions for the phenomenon (Appendix B). Students will engage with an image of people dressed for various professions and determine who is a scientist. Each student will make at least one observation as to why they think some are scientists. This will lead into students creating their own definition of the word scientist. During the explore part of the lesson students will explore descriptions of various fields of science through a gallery walk and will look for patterns and similarities to create a universal definition of a scientist (Appendix B). Students will then share their models (definitions) of a scientist and explain their thought process. The teacher will then share the dictionary definition scientist. To elaborate, the class will pull aspects from their definitions and the dictionary definitions to make a class description of a scientist. To evaluate, students will redetermine which of the people can be considered scientists. The goal is for their perspective on who scientists can be to change.

After the completion of the 5E lesson, defining a scientist, they should complete the Scientific Literacy Self-confidence Survey to connect their understanding of science and scientists to scientific literacy (Appendix A). The teacher can preface the survey by providing definitions of general literacy which can include the ability to read and write or the capability of understanding. They may also point out that there are many types of literacy including data-literacy, media literacy, civic and ethical literacy. After introduction and explanation students will complete the survey which includes explaining scientific literacy. The teacher can encourage students to think about their definition of a scientist while they fill out the survey. Defining a scientist and completing the Scientific Literacy Self-confidence Survey will hopefully create new perspectives of science and how anyone can be a scientist. After the survey teachers should start their normal routines and units and the following 5E lessons can be incorporated throughout. The focus of these lessons is on how utilizing and understanding crosscutting concepts would strengthen scientific literacy. The lessons can be adapted to suit different disciplinary core ideas so they can be added to a teacher's current units.

Focusing on Crosscutting Concepts

Lessons were created using a 5E format and focus on incorporating one or two crosscutting concepts. After each 5E lesson, students will have to read a peer reviewed science journal article that was modified to a lower reading level. This will be assigned as independent work or homework. The articles are categorized as Science Journals for Kids and Science Journals for Teens which have a slightly higher reading level. Every science journal comes with understanding questions that students will answer on their own. With the combination of students observing and working with phenomena through the scope of CCCs and reading about studies and experiments, students will strengthen their scientific literacy skills.

Lesson 2: Understanding Patterns and Cause and Effect

The first crosscutting lesson will focus on observing and determining patterns and cause and effect from a phenomenon through data analysis (Appendix C). This lesson will be carried out over a series of four to five classes. To engage, students will observe a phenomenon of two balls rolling down an inclined plane at the same time. Students will record observations and then watch the phenomenon again. To explore, students will design an experiment. They will be split into groups and provided with an inquiry question that will lead to an explore activity that involves students designing their own experiment and collecting their own data. Students should have their investigation planned out almost entirely by the end of the first period. At the start of the next class students will double check their plans and then carry out their investigation and collect data. Students will have the entire class period to gather data and if they have extra time can move on to data analysis. The following class period will be focused on analysis of data, which involves creating multiple graphs from the data and choosing one that best explains the relationship through cause and effect and patterns in the data. The focus of the lesson is the data analysis, and the lesson can be modified to fit different disciplinary core ideas depending on what is chosen for the inquiry question. On the fourth day, the teacher will use the class's data to explain the relationship between kinetic energy, mass and speed. The teacher will then ask the students to fill out a half sheet worksheet with fill in the blanks for three cause and effect sentences involving the three factors (Appendix C). When complete, the teacher will perform one final demonstration to connect mass and speed more clearly to kinetic energy. It will be the same as the original demonstration, except this time there will be wooden blocks at the bottom of the inclined plane. In the evaluate part of the lesson the following day, students will write a paragraph using a Claim, Evidence and Reasoning model to answer the question "What is the relationship between kinetic energy, mass, and speed?". In the paragraph, students should mention how the data formed certain patterns showing their understanding of the cause and effect of mass and speed on kinetic energy. To extend the lesson students will read a science journal and examine the data in the article. For future extension, the practice of students creating multiple styles of graphs to work through the best way to analyze their data can be repeated in new experiments.

Lesson 3: Systems and Models in Science Journal Articles

The second crosscutting concept lesson focuses on the CCC, systems and system models, through the scope of scientific text (Appendix D). The lesson is structured over three days with the first being an introduction to the topic. To engage, students are introduced to the question "Why are people more likely to get sick when it is cold?". Students will engage in a brainstorm activity and determine possible answers (hypotheses) to the question. During this time the teacher can determine what students already know and any misconceptions they may have. Then students will partner up and plan an investigation to support or disprove the hypothesis to the question that they came up. The investigation is a theoretical one, so materials and time restraints should not affect what the students can plan. This will conclude the first period and if students finish with extra time, they can share their investigation plans with the entire class. At the start of the next period, the teacher will explain how scientists have already studied this phenomenon and have come up with a conclusion. To explore the teacher will hand out the article "Why are people more likely to get sick when it is cold?", along with two graphic organizers (Huang et al., 2023; NGSS Appendix G, 2013). The teacher will explain the graphic organizers and students will begin working independently. During this time the teacher should circulate the room and ask students probing questions as they work. Students will have the entire class period, except for the last five minutes, to read the article and fill out the two graphic organizers. The teacher will hand out post-it notes at the five-minute mark and ask students to write down what they think the most important part of the article was. The responses from this exit ticket will be used as a formative assessment for their reading comprehension. On the last day, for the first half of the class, the teacher should explain the article highlighting any potential misconceptions. During this time, the teacher will also share an example of a completed graphic organizer (Appendix D). When going over the graphic organizer, students should have theirs out and should be encouraged to add to or clarify their responses. For the second half of class, students will complete the understanding questions that are attached to the science journal. They should be encouraged to use both the article and their graphic organizers to answer the questions. Students will be evaluated on their responses. To extend the lesson, there will be an exit ticket with the questions "Will this information affect the decisions you make?" or "Has this changed your frame of thought around your own health habits especially in the winter?". The two questions will be displayed on the board and a blank half sheet of paper will be handed out for the exit ticket. Students will have the option of answering one or both questions.

Lesson 4: Structure and Function and Stability and Change

The next lesson focuses on two CCCs: structure and function, and stability and change. The lesson is spread across four days (Appendix E). To engage, students will be introduced to a scenario about two chefs. They will have to speculate, argue for and support their ideas for why one chef will perform better than the other. The class will take part in discussions where they will have to support their claim. The class will end with students writing a one sentence summary about the most important ideas from the class. The second day will consist of exploring the topic more. Students will read the science journal article, “Why Don’t Whales Get Cancer?” (Tollis et al., 2024). While reading, students will complete the Science Journal Reading Chart (Appendix E). For the last ten minutes of class students will form groups of four and compare their charts. Students will be doing the explaining for this lesson. On the third day, the groups from the day before will present the similarities and differences of their charts to the rest of the class. Students will then have 15-20 minutes to independently answer the understanding questions from the article. During the last ten minutes of class, the teacher will go over the answers to the questions and students can correct their work. To evaluate, students will write a paragraph connecting the chef scenario to the whale article. Students will use the claim, evidence, reasoning worksheet to write their paragraph (Appendix E). To extend, students will be given a new science journal to read and have the opportunity to use the Science Journal Reading Chart.

Lesson 5: Energy and Matter, and Scale, Proportion and Quantity

The last lesson will focus on the crosscutting concepts of energy and matter, and scale, proportion, and quantity (Appendix F). It will be an example of a lesson that follows the guidelines for Indian Education for All. The lesson will be taught over two 45-minute class periods. To engage, the lesson starts with the teacher proposing a question to the class involving sound traveling through matter followed by a short discussion. The teacher will then introduce the class to a phenomenon about American Indian Plains nations hunting techniques. The teacher will explain how hunters would put their ear to the ground to learn about near and distant buffalo herds that they cannot see. To explore students will speculate “How did Plains Indian camps differentiate between herds of buffalo and other camps (including enemy camps) on horseback?”.

Students will then be instructed to recreate potential buffalo herds' sounds using everyday materials and speculate what inferences could be made about herds and hunting. Students will be placed into groups of four to do this and during this time they are to fill out a worksheet to record their work (Appendix F). The following class periods, students will explain their findings and the class will discuss and argue them. After, the teacher will explain typical inferences that were made by American Indian Plains nations, including how they determined the size and quantity of herds. To evaluate, students will answer the question "How is energy transferred from place to place through sound?". To extend and wrap up the lesson, the teacher can have students write a paragraph or two explaining how Native knowledge is an example of scientific literacy.

CHAPTER FOUR

PROFESSIONAL REFLECTION

Guidance for Implementation

The lessons provided are meant to be used in middle school science classes. The lessons are not meant to be taught together, but rather as supplements to an array of disciplinary core ideas and units. Along with the specified CCCs, each lesson focuses on vocabulary, data comprehension, reading comprehension or a combination of the three. Each lesson goes with a different disciplinary core idea, but the structure of the lessons and tools used in them can be taken and modified to fit any core concept.

Lesson 1: Defining a Scientist

For the first lesson, defining a scientist, the only prior knowledge students need is knowing in general what science is. Because of this, this lesson can easily be adapted for any age including elementary and high school. The purpose of this lesson is to gauge student understanding of science in general and who can participate in it. It is important to encourage students during the lesson to understand that anybody can be a scientist, including themselves. For optimal learning it is best for this lesson to be one of the very first lessons taught during the year. Teachers are encouraged to redo this same lesson at the end of the year to evaluate student growth. It can even be done in the middle of the year, as well, to further assess student growth in understanding of what science is and who scientists are. For this lesson, instruction can be structured into a presentation for optimal learning (Appendix G). This is a singular lesson, so teachers can start with unit they normally use at the start of the school year after it. To expand the lesson, the teacher can have students explain how they are scientists, either by writing a short essay about it or drawing an illustration with a short description.

Lesson 2: Understanding Patterns and Cause and Effect

For this lesson to be successful, students need to know the basics of graphing and understand the concepts of speed, mass and kinetic energy. For graphing, students should know how to create both bar and scatter plots. Each graph should have labeled axes and a title. Students should know the difference between the x- and y- axis and have experience graphing data using x and y tables. Based on this prior knowledge they will be able to turn the data that they collect into graphical representations of their choice. To collect data, students need a basic understanding of mass and speed. They need to know how to use digital scales to measure mass, including how to zero a scale. For speed, students need to understand that they cannot measure it directly. Students need to know how to measure time using a stopwatch and distance using a measuring tape or a ruler to calculate speed. Students will also need to have basic knowledge of energy, specifically that energy is the ability to do work or cause change and that kinetic energy is the energy of motion.

For optimal learning this lesson should be completed after basic concepts of motion have been covered. This ensures that students know the basics of speed. It can be completed towards the end of a unit on motion and energy, but before kinetic energy is covered in detail. This lesson provides an introduction to kinetic energy. To execute the lesson effectively it is important for students to understand that trial and error is necessary to create successful graphs in order to visualize relationships. Materials provided by the teacher in this lesson are lab directions, a cause and effect half sheet worksheet and a CER worksheet. All three of these can be modified to best suit a teacher's class and can also be modified and used for lessons focused on different disciplinary core ideas.

Lesson 3: Systems and Models in Science Journal Articles

Before engaging with this lesson, students should have a basic understanding of the levels of organization and basic functions of the immune system. The levels of organization are cells, tissue, organs, organ systems and organisms. Students should know that each cell in an organism has its own specific function and that groups of cells work together to perform tasks. Students should know that the basic function of the immune system is to protect the body from outside organisms. For optimal learning this lesson can be taught towards the end of a unit on levels of organization. This lesson focuses on reading comprehension using Frayer models and an adapted Frayer model. These models focus on vocabulary and looking at words from different perspectives to increase understanding. These perspectives include thinking about examples, examples of antonyms, characteristics, and parts of speech. The adapted Frayer model focuses on a scientific system rather than a vocabulary word. It is important for students to work on these models while reading the articles rather than at the end. This will help students comprehend while they are reading instead of getting to the end and wondering what this means. Students will often read something just to say that they read it, rather than thinking about the text while they are reading. Having students actively fill out the models while reading forces them to comprehend the text instead of just getting through it.

Lesson 4: Structure and Function and Stability and Change

For this lesson it is important for students to have been previously introduced to DNA, cells, and replication. Students' understanding of DNA and replication does not need to be in depth because the science journal does a good job of explaining it, but students should be familiar with the words. This lesson can be used as an introduction to a unit on DNA and reproduction or during anytime in the unit. For this lesson, the science journal article "Why are people more likely to get sick when it is cold?" (Huang et al., 2023) comes in two modified reading levels. One is a higher reading level targeted towards teens, and one is a lower reading level targeted to elementary and middle school aged students. For optimal learning, the teacher should use the version that best supports their students. I have used both the Science Journal for Teens and the Science Journal for Kids in seventh and eighth grade science classes. I use both because I always try to choose an article that connects to the disciplinary core idea that we are working on. Sometimes that is an article targeted towards teens and sometimes it is an article target towards kids (elementary students). Since most of my students are struggling readers, the articles targeted towards kids are easier for them, but the articles targeted towards teens are a good challenge for them.

Lesson 5: Energy and Matter and Scale, Proportion and Quantity

For this lesson it is important for students to understand the basics of energy before the lesson. They should know that sound is a form of energy that creates vibrations that our ears sense. This lesson follows fourth grade NGSS standards but can still be used in middle school as a supplemental lesson to strengthen scientific literacy. The lesson can be used in units covering energy or force. For optimal learning, it is important during the explain segment of the lesson for the teacher to make clear connections to scale, proportion, and quantity. The connections to energy and matter are straightforward and somewhat obvious, so students should make those easily. But the connections to scale, proportion and quantity are more abstract and require looking at the phenomena deeper.

Professional Development

When I began the Master of Science in Science Education (MSSE) program at Montana State University, I was just starting my fourth year of teaching. At this point I had taught middle school math for three years and fifth grade science for two years. I had also never taken an official education class before this, since I earned my bachelor's degree in Chemistry. I was able to teach without a teaching degree, since I am located at a private school. Now, two years later I have taken a variety of education courses and have just finished my fifth full year of teaching. This past year, my teaching load changed from three math classes, a science class and a fifth random class to four science classes and a fifth random class. Going from teaching one science class to four classes has given me ample opportunity to use what I have learned in my MSSE classes.

From my first year teaching science to now, I have changed greatly as a practitioner. Before being a part of the MSSE program, my lessons did not involve much inquiry. They were often me explaining science phenomena to meet standard concepts and students memorizing the important aspects of them through writing notes. While I still have students take notes, the amount of note-taking is drastically less. Before starting a new topic, I now always make sure to start with a phenomenon event. Since I teach middle school, routine is very important to create an environment conducive to learning. To create routine in my class I start every day with a phenomenon. Sometimes it is a large phenomenon event that involves an activity, but most of the time it is something simple displayed on the board like a picture, gif, graph, or short video that connects to what we are learning. At the start of each class, students are shown the phenomenon and are asked to make one observation and one inference. They have a minute to think of them and then I get three to four students to share. When students share, they must specify whether they are giving an inference or an observation.

Over the years, I have observed my students struggling with reading comprehension. I realized that reading struggles are a hurdle for understanding science. Because of this I began to focus on scientific literacy. To do this I had head to get a better understanding of it myself. I learned that scientific literacy is how we view and think about through world daily through the lens of science. I increased lessons involving students taking part in inquiry to build skills of scientific literacy. In addition, I started to incorporate reading science literature, specifically research journals, into my classes. Since my students were below average in reading, I tried to get a better understanding of crosscutting concepts to help support students' comprehension. I wanted to make sure I was incorporating them into my lessons. Before taking my MSSE courses I had not focused on how important CCCs are to teaching and understanding science and had had left them on the back burner while planning my lessons. Through designing the lessons described in this paper and taking numerous MSSE courses I have become more aware of the big picture goals of science education. These goals are developing understanding of disciplinary core ideas in students through building skills providing tools for them that can be used anywhere to make connections and think critically about how and why things work or appear. Overall MSSE has caused my approach to teaching science evolve from students reiterating concepts to students discovering those concepts through inquiry and reading about scientific inquiry in science journal articles.

To continue focusing on scientific literacy, especially in the context of reading comprehension, I hope to continue incorporating reading science journals. An idea I had for this to create a journal club type activity. Normally I have students read journals that I assigned based on the disciplinary core idea that we are working on. For the journal club the idea would be that students can choose whatever one they want. They would read the journal and create a short two to five minute presentation to share with the class or a small group. The hope is for this to become a regular routine maybe doing once or twice a month.

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APPENDICES

APPENDIX A

SCIENTIFIC LITERACY SELF-CONFIDENCE SURVEY

1. How would you describe your familiarity with science literacy (scientific literacy)?

   1 – not at all 2 – Slightly 3 – Somewhat 4 – Moderately 5 – Extremely

2. In your own words, create a definition for science literacy (scientific literacy).

3. How often do you look for patterns when trying to understand science readings and data?

   1 – Never 2 – Almost never 3 –Sometimes 4 – Almost every time 5 – Every time

4. How often do you think about cause and effect when trying to understand science readings and data?

   1 – Never 2 – Almost never 3 – Sometimes 4 – Almost every time 5 – Every time

5. How often do you look at scale, proportions, and quantity (amount) when trying to understand science readings and data?

   1 – Never 2 – Almost never 3 –Sometimes 4 – Almost every time 5 – Every time

6. How often do you look at the structure (shape) and function (it's job) when trying to understand science readings and data?

   1 – Never 2 – Almost never 3 –Sometimes 4 – Almost every time 5 – Every time

7. How often do you look for systems and system models when trying to understand science readings and data?

   1 – Never 2 – Almost never 3 –Sometimes 4 – Almost every time 5 – Every time

8. How often do you think about energy and matter when trying to understand science readings and data?

   1 – Never 2 – Almost never 3 –Sometimes 4 – Almost every time 5 – Every time

9. How often do you think about stability and change when trying to understand science readings and data?

   1 – Never 2 – Almost never 3 –Sometimes 4 – Almost every time 5 – Every time

APPENDIX B

5 E LESSON #1: DEFINING A SCIENTIST

5 E LESSON PLA N: DEFINING A SCIENTIST

Grade/ Grade Band: middle school	**Topic:** Science Introduction	**Two 45-minute periods**
Brief Lesson Description: This lesson is to be used at the beginning of a course to get a baseline of students' thoughts about science. Since this is an introductory lesson, there is not a specific core idea, but rather the general idea of science. The goal is to assess students' understanding of science. Students will start by choosing who they perceive as scientists from a picture of people. They will need to provide at least one observation to support their claim. Then there will be a gallery walk with various scientist definitions. Students will go around and record any similarities or key points and then create a universal definition of the word scientist. Students will then share their definitions and, as a class, create a final definition. Once a consensus is made for the definition, students will go back and look at the image of the people. They will reidentify the scientists and use the class definition and observations to support their new claim. Lastly, they will fill out the Scientific Literacy Self-Confidence Survey.		
Performance Expectation(s): Create a definition of the word scientist that encompasses and relates to all fields of science and identify examples of scientists.		
Specific Learning Outcomes: Students will gain a better understanding of science and make a realization that anyone who thinks scientifically can be scientists. One thinks scientifically by making observations and thinking about them critically in an effort to learn more about the Earth and universe.		
Narrative / Background Information		
Prior Student Knowledge: This lesson is designed to assess prior knowledge surrounding science.		
Science & Engineering Practices: **Analyzing and Interpreting Data** • Students will observe the phenomenon and record qualitative data. Then they will analyze qualitative data by identifying similarities, differences and patterns. **Developing and using Models** • make claims based on evidence to construct explanations of phenomena **Engaging in Argument from Evidence** • Class discussion where students will argue the most important aspects of definitions based on prior knowledge and evidence provided.	**Disciplinary Core Ideas:** **N/A**	**Crosscutting Concepts:** **Patterns** • All scientists have similarities including using observational skills and inquiry to learn more about the natural world and universe. Students will identify these similarities by finding patterns in various scientist descriptions.

Obtaining, Evaluating, and Communicate Info • Develop a definition of the word scientist from initial phenomeona, gallery walk, and information provided • Students share their definitions with class. • In a group discussion each definition will be analyzed and evaluated. • From the discussion a group definition is created		

Connections to Nature of Science
Hypotheses are revised as new evidence is collected and obtained.
Students' initial explanations and final explanations of the phenomenon will be different.
Science is a creative process.
Students' first draft of definitions will most likely differ

Possible Preconceptions/Misconceptions:
Students most likely believe that scientists are only those who work in labs and do experiments.

LESSON PLAN – 5-E Model

ENGAGE: The phenomenon for this lesson is simple but still engaging. Students will be shown an image of a group of various professionals. Each professional will be labeled with a number (Figure 3). The labels are numbers rather than names as to not create bias for student observations. Students will point out which professionals are scientists. Students will be given three minutes to just observe and look at the image before being given the question. Once the three minutes is up, the teacher will ask "Which of these professionals are scientists?". For each person that they pointed out, students would need to provide an observation supporting why they thought each was a scientist. Students would record the number and observation in the science journal notebook. (For my middle school classes, there is a notes section as well as a science journal section. These observations would go in the journal section of the notebook). Students will then create a rough draft for a definition of the word scientist. Potential observations for the phenomena are, four and six are wearing lab coats so they must be a scientist. Eight has a roll of design plans which could mean he uses engineering. Five has a mask on so he must work with sick people which means he uses science to help them.

EXPLORE: Students will then explore and observe different types of scientists through a gallery walk (Figure 4). The gallery walk will include various definitions of specific types of scientists including biologist, chemist, physicist, ecologist, and astronomer. Each slide should be printed on its own page and hung up around the room. Students are instructed to keep in mind the questions: "What is a scientist and Who is a scientist?". As students go around the gallery walk, they are to record in the science journals any similarities and key words or phrases that jump out to them. Students are encouraged to discuss the gallery pieces with their classmates and to return previous gallery posters after looking at different ones. Since there are 5 parts of the gallery walk, the teacher can allow for an estimated five to 10 minutes of time to make observations. It is estimated at about one to two minutes for each gallery piece. Teachers can add gallery pieces that connect to the goal of obtaining of greater understanding of the questions: *What is a scientist* and *Who is a scientist?*

After students record their observations, they will reread their definition of a scientist and their observations from the gallery walk. Then they will compare the two and determine whether they need to update their definition. Students will be given five minutes to reflect and make changes. They should be instructed that if they are making changes, not to erase their first draft, but instead create a draft number two. This will allow them to better reflect on their thought process at the end.
EXPLAIN: Concepts: After students create a second draft of the word scientist, they will share their definition with the class. The teacher will record each student's definition that can be displayed to the whole class. Once all the definitions are shared and recorded, students will take a few minutes to reread them all. As a class they will highlight the key parts of each definition (Figure 5). This will be in the form of a class discussion with hopefully participation from every student. Students are encouraged to engage in argument to determine the most important parts of each definition. Students can also determine that some definitions need to be thrown away. After the class determines the key points of each definition, the teacher will explain two dictionary definitions of the word scientist. Students will then have time to reflect again to analyze their definitions in comparison to the dictionary definitions. They are encouraged to record any differences or patterns in their science journal. After they have time to organize their thoughts, the class will engage in another discussion to determine a final definition. Students will take from the highlighted aspects of student definitions and the dictionary definitions to create a class-wide definition of the word scientist. This will involve students piecing together the highlighted portions like a puzzle and potentially adding aspects from the dictionary definition. Once the class and teacher are content with their definition, they will record it in the notes section of their notebook. To help students determine whether they are content with the definition, the teacher can ask *Does this describe ________?*. The blank could include the words on the gallery walk or other people in the world of science. The goal is for them to create a universal definition that could describe all people in science regardless of the field. It is a hope that they create a definition that describes someone using observational skills and inquiry to learn more about the natural world and universe.
EVALUATE: The goal of the lesson is to create a definition of the word scientist that encompasses and relates to all fields of science and to identify examples of scientists. Through this the hope is to broaden and strengthen student understanding of science. To evaluate student understanding, students will be asked to re-identify the scientists in an image of people dressed for various professions. They will then need to support their claim with evidence from the class definition and inferences that they made about the appearance of each professional. This can be written in their science journal or on an exit ticket. A second part that can be added to evaluate student understanding is for the teacher to ask the class how they personally are a scientist. They would again use the definition that the class created of the word scientist to support their claim.
EXTEND: This lesson can be repeated in the middle of the year and/or at the end of the year. This will give the teacher data that can be used to analyze how student understanding has changed over the course. The new perspective created during this lesson will be carried over to every lesson and inquiry activity. It will allow for students to see themselves as scientists, as well as understand that many things fall under the umbrella of science that they had not realized before.

ENGAGE REOSURCES: PROFESSIONALS ILLUSTRATION

Figure 3. Engage phenomena: “Who is a Scientist?”.

EXPLORE REOSURCES: GALLERY WALK

Biologist

"Biology is the study of living things. A biologist is a scientist who studies biology. Biologists try to understand the natural world and the things that live in it. These things include plants, animals, fungi, protozoa, algae, bacteria, and viruses."

Chemists

Those who "study the substances that make up **matter**—everything that takes up space in the universe. They also study the changes that take place when substances are combined. These changes are called chemical reactions."

Physicists

Physicists study **matter** and the **forces** (pushes or pulls) that act on it. (Matter is what makes up all physical objects.) Physicists also study many different forms of **energy**.

Ecologist

"A person who studies the natural relationships between the air, land, water, animals, plants, etc."

Astronomer

A person who is skilled in astronomy or who makes observations of celestial phenomena

-Webster's Dictionary

Figure 4: Gallery walk slides with various scientist definitions.

EXPLAIN REOSURCES: EXPAMPLES OF STUDENT DEFINITONS

What is Science or What is a scientist?

"A person who works/researches different branches of science. They do this by observing, discovering, testing, studying and researching."

"A person that's really smart and can research practically everything" -

"Science is the discovery of all types of things coming from atoms. Cures can be found through science. Scientists can find all things from backwards and forwards analysis."

"Learning new things and being creative and trying to learn new cures."

What is Science or What is a scientist?

"Science is a way to discover math and the world around us like plants and animals. Scientist test plants and work with test tubes to find any information. They are someone who has knowledge, also travels different places on the planet."

"A Scientist make experiments and do research on tech. You have to be smart."

"Scientists discover new plans and makes new things everyday"

"Science is researching, studying, learning, conducting experiments and questioning different subjects. To be a good scientist you need to have a creative mind and the ability to explore different subjects and new ideas"

Figure 5: Student examples of definitions of scientists with key parts highlighted.

APPENDIX C

5 E LESSON #2: UNDERSTANDING KINETIC ENERGY BY ANALYZING DATA

5 E LESSON PLAN: DECIPHERING DATA USING PATTERNS AND CAUSE AND EFFECT

Grade/ Grade Band: Middle School	**Topic:** Motion and Energy	**Five 45-minute periods**
Brief Lesson Description: This lesson is designed to be part of a unit focused on energy, specifically the relationship between kinetic energy, mass, and speed. The purpose is to build habits around data analysis to increase student scientific literacy skills. The core idea covered in this lesson is *Definitions of Energy*. The lesson starts with students observing various balls rolling down an inclined plane. The teacher will ask for students to share their observations and then for them to define speed, mass and kinetic energy. Students will then be given the question, "What is the relationship between kinetic energy and mass, and kinetic energy and speed?" and asked to design and carry out an experiment to answer it. Students will be placed into groups to carry out the investigation and analyze their data. For the data analysis, each group is required to create four to five different graphs using their data. They will then choose two or three of the graphs to identify the relationships. During the following class, the teacher will use class data to explain the relationships. After the explanation, students will receive a cause and effect worksheet to fill out. Then the teacher will do a second demo but this time at the bottom of the inclined plane are bowling pins or something similar. The teacher will explain that more energy allows more work to be done, so more bowling pins are knocked down. Students will then complete a Claim, Evidence, Reasoning worksheet.		
Performance Expectation(s): Create a graph to display how speed and mass of an object relate to kinetic energy		
Specific Learning Outcomes: 1. Identify the relationship between kinetic energy and speed, and kinetic energy and speed. 2. Understand when to utilize bar graphs compared to line and scatter plots.		
Narrative / Background Information		
Prior Student Knowledge: Kinetic energy is the energy of motion. Energy is the ability to do work or cause change.		
Science & Engineering Practices: **Asking Questions and Defining Problems** • Ask questions about a phenomenon • Ask questions in regard to how to best collect and analyze data **Analyzing and interpreting data** • Organize data, create graphs and look for trends.	**Disciplinary Core Ideas:** **MS-PS3-1. Construct and interpret graphical displays of data to describe the relationships of kinetic energy to the mass and speed of an object.**	**Crosscutting Concepts:** **Cause and Effect** • If the mass of the object increases, the speed of the object going down an inclined plane will increase. • The greater the kinetic energy of something, the greater the speed. More mass = more kinetic energy **Patterns** • Trends on the graphs show specific patterns
Connections to Nature of Science **Based on Empirical Evidence** Students collected empirical data to support or refute their claim. **Science searches for cause-and-effect relationships to explain natural events.** Students collect data to search for the effect mass and speed have on kinetic energy. **Science is a creative process.** Students plan and create their own experiments based on a common question.		

Possible Preconceptions/Misconceptions:
If the speed is doubled so is the kinetic energy.
Only moving things have energy.

LESSON PLAN – 5-E Model

ENGAGE: At the start of class, the teacher will present an inclined plane with two balls with different masses at the top. The teacher will not mention that they have different masses. The teacher will release both balls at the same time and the class will observe. After the initial release, the teacher will ask students what they observed. Potential observations: one was faster than the other, one got to the bottom quicker, they must weigh different amounts, one has more kinetic energy. The teacher will then redo the demonstration. From this, students will develop questions about the phenomenon. Once they all have a question, the teacher will ask "How many of you have questions that involve energy, mass or speed?". Hopefully a majority of the class would have raised their hands. Then the teacher will ask for students to define the three words. The teacher will give them a moment to think and then can ask for volunteers or call on students at random to define the three words.

Explanation of Phenomenon: The mass of an object is proportional to an object's kinetic energy. This means that the ball with the greater mass will have more kinetic energy than the other. This relates to speed because kinetic energy increases by the square of the speed. Overall, this means that the greater the mass of the object, the greater the speed and kinetic energy. This explains why two balls with different masses will have different speeds. Their mass affects their kinetic energy, which affects their speed.

EXPLORE: At this point students know mass and kinetic energy are factors affecting the speed of an object but not exactly how they are related. Some may have a good idea about the type of relationship they have. The engage phase of the lesson took half a period, so students will have half a period to start exploring and planning an investigation. Students will be given a worksheet titled Examining the Relationship Between Kinetic Energy, Mass and Speed. They will be instructed to plan an experiment that explains the relationship between the three. The goal of the investigation is to describe the relationship of kinetic energy to the mass and speed of the object using graphed data. Students will be placed into groups of four to design and carry out the experiment. For designing the experiment, students will be required to use the following materials: inclined plane, balls (variety of masses), scales, stopwatches, measuring tape, and rulers. Other materials will also be available, including wooden blocks. At the end of the class period, students should have most of their investigation planned.

At the start of the next class, they will finish up their plans making sure that they involve measuring mass, time, and distance. To ensure that they have enough time to collect data, only allow 15 minutes for them to finish up their procedure. Before they begin their experiment, the teacher will remind students that they should have more than one trial for each run that they are testing. The teacher should tell them to keep in mind why this is important. It is important because it will allow students to observe. Then they will begin their experiments. The teacher should be circulating the room probing students to make sure they are on task. The goal is to have all the data collected by the end of the period.

Potential experiments could include measuring the mass, distance and time for various balls rolling down an inclined plane. From the distance and time, speed can be calculated and compared to mass. Another part of the experiment could be measuring the different massed balls' abilities to knock down blocks at the bottom of an incline plane, potentially like bowling. This would allow data to be recorded in connection to relative kinetic energy.

On the third day, data analysis will be the focus. Students will be asked to create three to four different graphs using the data from the experiment. For each, they are encouraged to use different styles of graphs (ex. scatter, bar) as well as switch up the x and y variables. Before they begin, the teacher should do a quick review of basic types of graphs including scatter and bar graphs. They should encourage groups to be creative and if students need, they can look up different types of graphs. Students will oversee deciding the best way to analyze the data. From the four graphs created, they will choose one to two graphs that best describes the relationship between kinetic energy, mass, and speed. To choose, they will be instructed to look for trends (patterns), and cause and effect. After they choose one to two graphs that best describe the relationship, they will write a sentence describing the relationship using evidence from the data. It is important to note that some groups may have not measured kinetic energy, and groups that did only measured relative kinetic energy. This means that they will have to use their prior knowledge of kinetic energy to make connections.

EXPLAIN: The teacher should collect each group's data tables and combine them into one large data set. Depending on what groups specifically did for their experiment, the data will be put into one or more tables. Before the next class, the teacher should create two potential graphs using student data to describe the relationships. They should highlight any patterns or trends in the data to show and explain to the class. From these patterns present in the graphs the teacher will ask the students to fill out a half sheet worksheet with fill-in-the-blanks for three cause and effect sentences involving the three factors. Closing: The teacher will then explain the answers to the fill-in-the-blanks. The teacher will then explain that, based on the graphs and the cause and effect statements, there is a positive relationship between the three factors. As the mass increases, the speed increases. Both factors positively affect kinetic energy as well. To end the class, the teacher will then set up one more demonstration where there are six blocks standing straight up five inches away from the bottom of the inclined plane. The teacher will do three trials, each time releasing a different massed ball at the top of the inclined plane to roll down it. Before running the demo, the teacher will explain again how energy can be described as the ability to cause change. They will then explain that the class will observe relative kinetic energy by looking for changes in the block formation. The greater the change (the more blocks knocked down), the greater the kinetic energy.
EVALUATE: On the fifth day of the lesson students will be evaluated using the Claim, Evidence and Reasoning (CER) model. They will write a paragraph explaining how their data answers the question: "What is the relationship between kinetic energy, mass and speed?". When writing their paragraphs students will follow a CER model. The CER will be used to evaluate students' abilities to make connections between phenomena, in this case different massed balls rolling down an inclined plane. Students should use evidence from their experiment to support their claim. Students should then end their paragraph restating their claim.
EXTEND: Scientific discovery is fueled by collecting empirical data. To extend the importance of understanding data students will read a science journal article for homework. In the journal there will be empirical data turned into graphs that students will have to decipher. In addition to reading this article, students will be assigned the understanding questions complete for homework Students will continue to read science journals throughout the year. The goal is for them to use the data analysis skills practiced in this lesson as well as other comprehension skills to strengthen their understanding of scientific literature.

LAB INSTRUCTIONS: EXAMINING THE RELATIONSHIP BETWEEN KINETIC ENERGY, MASS, AND SPEED

Name: _________________________ Partners: ____________________________________

Examining the Relationship Between Kinetic Energy, Mass and Speed

Background:

Energy: the ability to do work or cause change
Kinetic Energy: energy of motion that is observed through movement.
Mass: the amount of matter in an object (measured in grams or kilograms)
Speed: change in position over time. **Speed = distance/ time**

Goal: Design and carry out an investigation that allows you to construct and interpret graphical displays of data to describe the relationships of kinetic energy to the mass of an object and to the speed of an object (MS-PS3-1).

Materials:

Required

- Balls (variety of masses)
- Inclined plane
- Stopwatch
- Measuring tape/ruler
- Scale

Optional

- Wooden blocks
- Hot-wheel cars
- Other

Procedure:

1. In your group design an experiment that allows you to answer the question
    - What is the relationship between kinetic energy, mass and speed?
2. Write out the procedure step by step and list any materials needed.
3. In your experiment you will need to measure
    - Mass of balls
    - Length of inclined plane
    - time
4. Carry out the experiment
    - Record all data in a table.
    - List any qualitative data points and potential human error
5. Data Analysis
    - Using your data create **3-4 DIFFERENT** graphs
        - Vary the type of graph
        - Vary the x and y axis/variables
        - Students may look up types of graphs for inspiration

- Each graph needs
  - Title
  - Axis labels
- Identify any trends or patterns in each graph
  - Is it linear?
  - What does linear tell us?
- Identify the cause and effect relationship for each graph
- As a group decide which graph best displays the relationship between kinetic energy, speed and mass
- Write a sentence to describe the relationship using evidence from the graphed data.

CAUSE AND EFFECT STAMENTS FILL IN THE BLANK

Name: _________________ Date: ___________

Relationships between speed, mass, and kinetic energy

1. As the mass ___________, the speed _______________
2. As the speed___________, the kinetic energy_______________
3. As the mass___________, the kinetic energy _______________

Name: _________________ Date: ___________

Relationships between speed, mass, and kinetic energy

4. As the mass ___________, the speed _______________
5. As the speed___________, the kinetic energy_______________
6. As the mass___________, the kinetic energy _______________

STUDENT CER FOR ASSESMENT

Name: ___________________________ **Date:** ______________

CLAIM EVIDENCE REASONING

Claim	A sentence that answers the question. (1 sentence)
Evidence	Use data from your experiment and your prior knowledge of the world that supports your claim. (2-3 sentences)
Reasoning	Explain how the evidence supports your claim. Explain the importance. (2-3 sentences)
	Restate claim (1 sentence)

Question: What is the relationship between the kinetic energy, mass, and speed of an object?

____

____

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APPENDIX D

5 E LESSON #3: UNDERSTANDING SYSTEMS AND MODELS VIA SCIENCE JOURNALS

5 E LESSON: UNDERSTANDING SYSTEMS AND MODELS VIA SCIENCE JOURNALS

Grade/ Grade Band: Middle School	**Topic:** Levels of Organization, Specialized Cells	**Three 45-minute periods**
Brief Lesson Description: The lesson is designed to be a supplement to a unit on the structure and function of living organisms, including cells. It is focused on ways to analyze systems to increase reading comprehension and scientific literacy. One of the topics that it will cover is how cells can have specialized functions. The core idea covered in this lesson is *Structure and Function.* To start the lesson students will be given the question, "Why are people more likely to get sick when it is cold?". Then students will be asked "What parts of your body would be factors to this phenomenon?", and asked to create a hypothesis. They are then tasked to design an experiment to prove or disprove their hypothesis. Students will then be given a science journal article to read that answers the question. While reading, students are to fill out four Frayer model diagrams and a modified diagram that highlights the scientific system mentioned in the article. The teacher will then explain the article. To assess understanding, students will answer the understanding questions that came with the article.		
Performance Expectation(s): Students should be able to identify the purpose, system, and results of a scientific research journal article.		
Specific Learning Outcomes: Strengthen reading comprehension skills to better identify the purpose, system, and results of a scientific study.		
Narrative / Background Information		
Prior Student Knowledge: The Immune System is one of the major organ systems in the human body. It is made up of organs that are made up of tissue that are made of specialized cells. The Immune System is a complex system that has many parts with different functions. The nose is part of it and has specialized cells to defend against foreign objects. Some of these specialized cells are ones that contain extracellular vesicles. These are tiny sacs that are released in the presence of foreign substances like bacteria, to fight and keep them from infecting the body (Huang et al., 2023).		
Science & Engineering Practices: Constructing explanations (for science) and designing solutions (for engineering) • Students create three hypotheses about the question at hand. • Students take one of their hypotheses and plan out an investigation to confirm or deny the hypothesis. **Developing and using Models** • Draw a model of the investigation carried out in the science journal **Engaging in Argument from Evidence** • Students discuss and argue with a partner which hypothesis is the most accurate based on prior knowledge and understanding of the phenomenon.	**Disciplinary Core Ideas:** MS-LS1-3 Use argument supported by evidence for how the body is a system of interacting subsystems composed of groups of cells. • Within cells, special structures are responsible for particular functions, and the cell membrane forms the boundary that controls what enters and leaves the cell. (MS-LS1-2) • In multicellular organisms, the body is a system of multiple interacting subsystems. These subsystems are groups of cells that work together to form tissues and organs that are specialized for particular body functions. (MS-LS1-3)	**Crosscutting Concepts:** **Systems and System Models** • The investigation involved extracting nasal cells from a human and studying them in a lab. The temperature of the nasal cavity that cells were extracted from affected how they treated the cells in the lab. **Structure and Function** • Cells are specialized. The shape and specialized parts of nasal cells allow for them to attack foreign matter.

Connections to Nature of Science

Science searches for cause-and-effect relationships to explain natural events.

Lower temperatures decrease the activity of specialized nasal cells' extracellular vesicles.

Scientific Knowledge Assumes an Order and Consistency in Natural Systems

Since there were common results for the selected nasal samples, we can conclude this is the case for all healthy humans.

Science is a Human Endeavor

The investigation was done not merely to learn more, but to better help human life.

LESSON PLAN – 5-E Model

ENGAGE: When students enter class, they will be presented with the following question on the board: "Why are people more likely to get sick when it is cold?". Then students will be asked "What parts of your body would be factors to this phenomenon?". Students will be instructed to hypothesize three possible answers to the questions. Each hypothesis should have an answer to the question and reasoning for why they think that. Students will record them in their science notebooks and be reminded they always need a date and title for each entry. A possible title suggestion would be "Why are people more likely to get sick when it is cold?". Students will have 10 minutes to create their three hypotheses. After the 10 minutes, they will be partnered up to discuss and explain their hypotheses to a classmate.

During partner time they will have five minutes to choose which hypothesis seems most accurate based on their prior experiences and knowledge. Using the chosen hypothesis, they will have another 15 minutes to brainstorm a basic experiment to prove or disprove their theory. The teacher will explain that this is a hypothetical experiment that will not be performed in class, so there are no material and time restraints. Their basic experiment must have defined parameters, including variables and constants, and state what kind of environment it will be performed in. They are instructed to record their hypothesis and experiment in their science notebooks. At the end of the 15 minutes, students will have the opportunity to explain their experiment, but will not be required to do so. This will bring the lesson up to the end of a class period.

EXPLORE: At the start of the next class, students are instructed to go back and reread their hypothesis from yesterday. Students will then be given a science journal to read, *Why are people more likely to get sick when it is cold?* (Huang et al., 2023). Before students begin reading, the teacher will provide them with two graphic organizers to fill out while reading (Figure 6,7). The first contains four Frayer model diagrams. Students will use this graphic organizer to map out four different scientific vocabulary words from the article that are unfamiliar. They should choose their words as they read the article. The vocabulary word will go in the center oval and then they should fill out each corner using the article and their prior knowledge. The four corners have the following labels: definition, characteristics, examples, and nonexamples. The second graphic organizer is adapted from the Frayer model to analyze the system of study. Students should fill this out after they have read the entire article and filled out the first graphic organizer. In the center, students should define the system that was being studied in five words or less. Then they can fill out the four corners using the article. The four corners are labeled as: characterize parameters, observations & inferences, draw a model, and things with similar behaviors. The teacher should instruct that since there is more space on this graphic organizer, that there should be more detailed responses on the second one. Students will have the entire class period to read and fill out the two graphic organizers. With this, the teacher may want to give time warnings as they near the end. With the last 10 minutes of class, each student will write on a post-it what they thought was the most important part of the article as an exit ticket.

EXPLAIN: After students complete the two graphic organizers and reading the article, the teacher will clarify any potentially confusing parts of the article as well as the results and conclusion. Then the teacher can share a completed graphic organizer about the system and explain how and why they filled out each corner (Figure 8). It is important to explain that it is possible to fill these out differently and still be correct. The great thing about these graphic organizers is that there are multiple ways to use them and a variety of accurate responses that can be used. Students can add to their graphic organizers at this time, but they should be instructed to not erase anything. If a student feels part of theirs was completely incorrect after looking at the teacher's, the teacher should instruct them to draw a single line through it. This will allow the teacher to see their original thoughts and use it as data for formative assessment. This should take 15 to 20 minutes.

EVALUATE: Throughout the lesson, the teacher will be roaming around the room probing students by asking questions relevant to the current task. This will provide formative assessment information as the lesson proceeds, as well as keep students focused. If a student has a question and the teacher observed the answer from a different student, they can ask the classmate who already figured it out to answer it. On the third day of the lesson, after the teacher shares their graphic organizer, students will answer the understanding questions on the last page of the science journal. Students will be instructed to answer the questions on a separate sheet of paper using complete sentences. The teacher should remind them that answers often need to be more than one sentence to answer the question completely. The understanding questions should be graded on correctness. In order to receive full credit, answers must have complete sentences and answer the questions fully and when required contain evidence from the article to support the answer. Students will be assigned an additional science journal to read and answer the understanding questions for independent work or homework. They will not be required to fill out the graphic organizers while reading but are welcome to complete them. Extra copies of the graphic organizers will be available if students want them.
EXTEND: A great part of the Science Journal for Kids/Teens library is that they always include in the conclusion how the journal can be related to the students' everyday lives. To extend the lesson, there will be an exit ticket with the questions "Will this information affect the decisions you make?" or "Has this changed your frame of thought around your own health habits especially in the winter?". The two questions will be displayed on the board and a blank half sheet of paper will be handed out for the exit ticket. Students have the option of answering one or both questions. This will allow the teacher to assess them as engaged citizens using their understanding of science to better the world, which is an aspect of scientific literacy. In addition to this article, throughout the year students will continue to read science journals. The goal is for them to use the comprehension skills practiced in this lesson as well as new ones to strengthen their understanding of scientific literature.

FRAYER MODEL GRAPHIC ORGANIZERS

Name: ____________________

Directions:

1. Choose four scientific words from the reading.
2. Write each word in the center ovals on the **BACK** graphic organizer
3. Fill out each square while you are reading the article
    a. You can pull information from the article OR prior knowledge
4. After you finish reading the entire article and complete the entire **BACK**, complete the **FRONT.**
5. Define the system of study in 5 words or less and write in the center circle.
6. Fill out four corners and be descriptive
    a. ****this should have more detail than the back

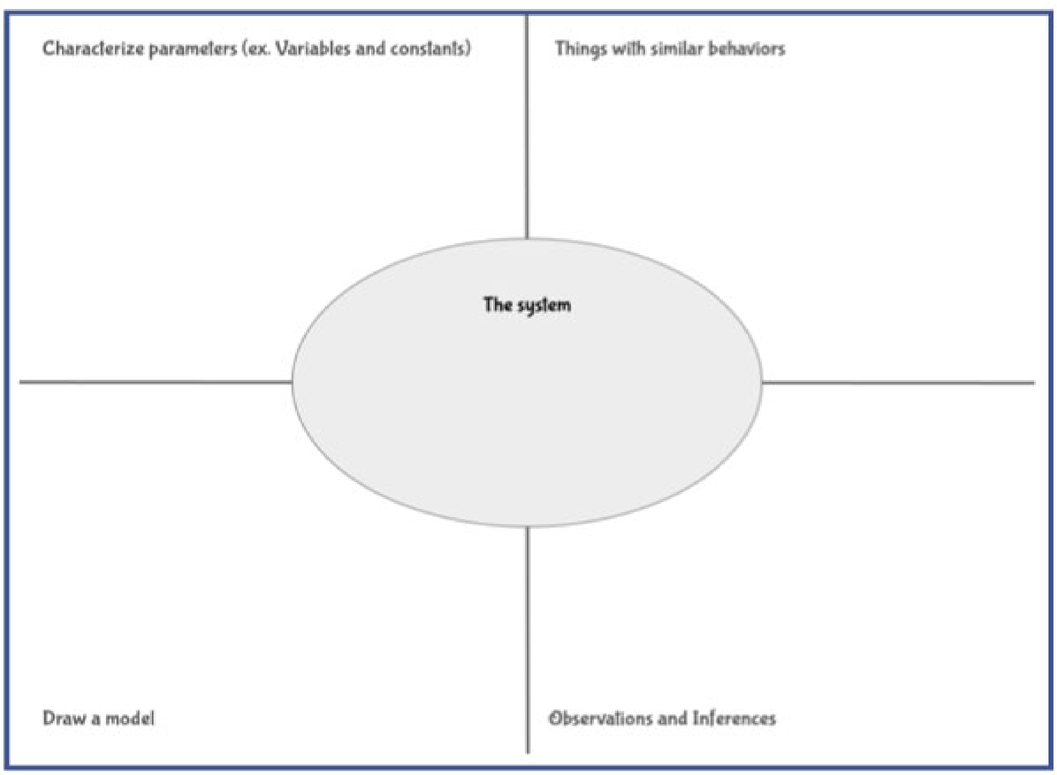


Figure 6: Graphic Organizer using an adapted Frayer model to focus on scientific systems in literature.

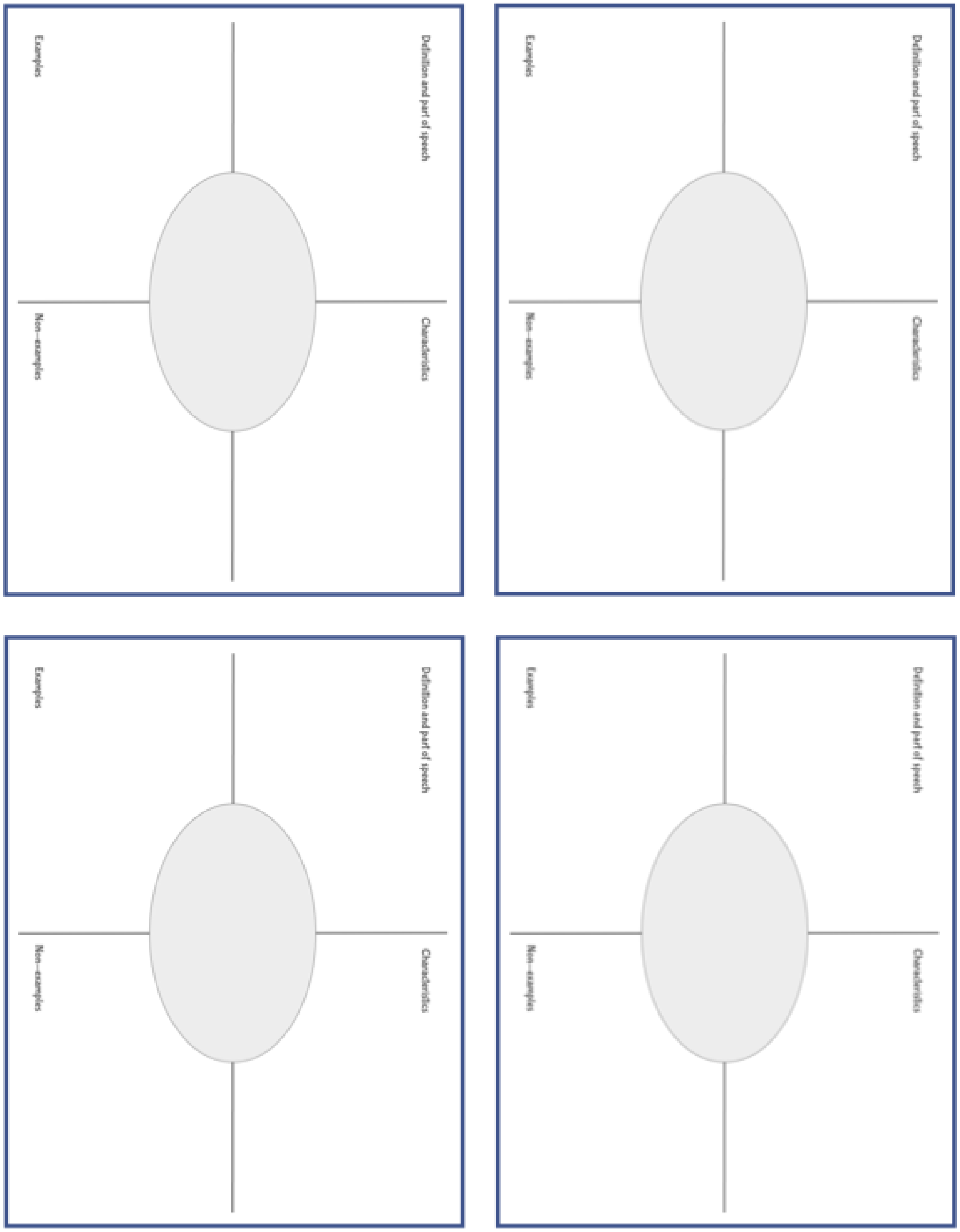
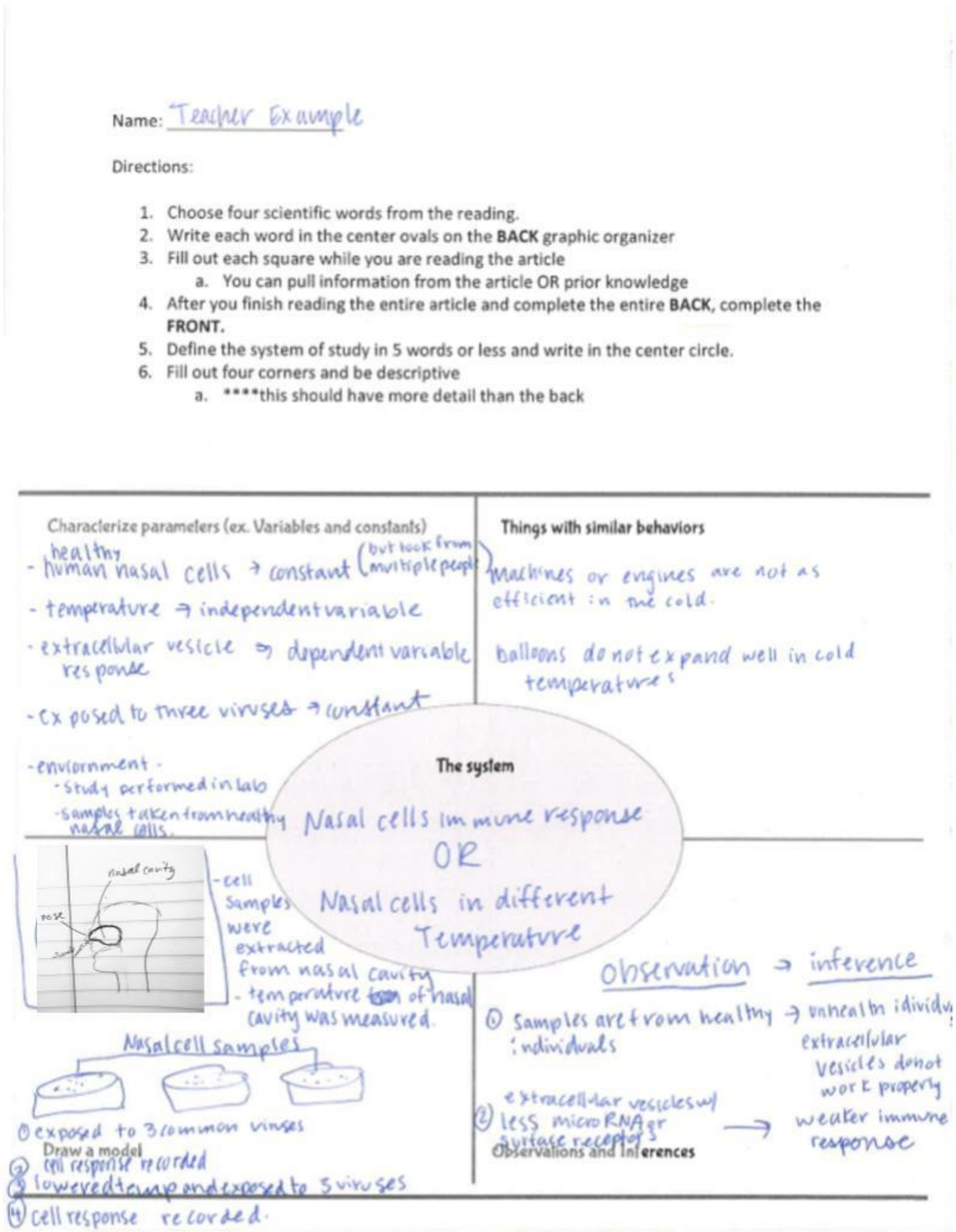


Figure 7: Frayer Model graphic organizer used to work on strengthening vocabulary.

TEACHER SAMPLE OF GRAPHIC ORGANIZER



Name: Teacher Example

Directions:

1. Choose four scientific words from the reading.
2. Write each word in the center ovals on the **BACK** graphic organizer
3. Fill out each square while you are reading the article
    a. You can pull information from the article OR prior knowledge
4. After you finish reading the entire article and complete the entire **BACK**, complete the **FRONT.**
5. Define the system of study in 5 words or less and write in the center circle.
6. Fill out four corners and be descriptive
    a. ****this should have more detail than the back

Characterize parameters (ex. Variables and constants)

- healthy human nasal cells → constant (but took from multiple people)
- temperature → independent variable
- extracellular vesicle response → dependent variable
- exposed to three viruses → constant
- environment -
  - study performed in lab
  - samples taken from healthy nasal cells.

Things with similar behaviors

Machines or engines are not as efficient in the cold.

balloons do not expand well in cold temperatures

The system

Nasal cells immune response

OR

Nasal cells in different Temperature

Draw a model

nasal cavity

nose

- cell samples were extracted from nasal cavity
- temperature of nasal cavity was measured.

Nasal cell samples

① exposed to 3 common viruses
② cell response recorded
③ lowered temp and exposed to 3 viruses
④ cell response recorded.

Observations and Inferences

observation → inference

① Samples are from healthy individuals → unhealthy individuals extracellular vesicles do not work properly

② extracellular vesicles w/ less micro RNA or surface receptors → weaker immune response

Figure 8:Teacher example of graphic Organizer using an adapted Frayer model to focus on scientific systems in literature.

APPENDIX E

5 E LESSON #4: STRUCTURE AND FUNCTION, AND STABILITY AND CHANGE

5 E LESSON #4 STRUCTURE AND FUNCTION, AND STABILITY AND CHANGE

Grade/ Grade Band: Middle School	**Topic:** Cell Replication and Mutations	**Four 45-minute periods**

Brief Lesson Description: This lesson is to be used as a supplement to a unit. It can be used exactly how it is on a unit about cells, evolution, or heredity, or its structure can be used with any core idea. The lesson falls under two core ideas: *Heredity: Inheritance and Variation of Traits and Biological Evolution: Unity and Diversity*. Students will be presented with a scenario about cooking and asked to make predictions about their performance. Students will be given the opportunity to debate and defend their predictions. Students will then read a science journal article about whales and cancer. While reading, students will fill out a graphic organizer that focuses on vocabulary, structure and function, and stability and change. Students will have a chance to review their charts with classmates. Then they will complete the understanding questions that were at the end of the article. The class will then go over the answers and the teacher will connect certain questions to either structure and function or stability and change. Students will then be asked to explain how the cooking scenario related to whales and cancer using Claim, Evidence and Reasoning.

Performance Expectation(s): Make connections between a whale's genome structure and replication process to its life stability and how life spans can vary.

Specific Learning Outcomes: Students can use the relationships between structure and function and stability and change to explain the benefits of whale cell reproduction.

Narrative / Background Information

Cells replicate every day. Sometimes in the replication process mutations occur. The immune system goes through replicated cells and looks for these mutations. When it finds them, it attacks and kills them. Cancer cells are a result of mutations during cell replication that slip past the immune system's quality control. These mutations multiply and turn into cancer cells.

Prior Student Knowledge:

Understand DNA and its basic functions including the idea of replication

Science & Engineering Practices:	**Disciplinary Core Ideas:**	**Crosscutting Concepts:**
Constructing explanations (for science) and designing solutions (for engineering) • Make inferences about the scenario (phenomenon) and provide evidence to explain the inferences. **Engaging in argument from evidence** • Develop claims using evidence from the article and prior experience. **Obtaining, Evaluating, and Communicate Info** • Class discussion • Present claims to class.	MS-LS-3 Heredity: Inheritance and Variation of Traits MS-LS3-1 Develop and use a model to describe why structural changes to genes (mutations) located on chromosomes may affect proteins and may result in harmful, beneficial, or neutral effects to the structure and function of the organism. Students make connections between genomes of humpback whales and other similar species and their ability to prevent cancer. Changes (mutations) to genes can result in changes to proteins, which can affect the structures and functions of the organism and thereby change traits. (MS-LS3-1)	**Structure and Function** • Size and shape of large segmental duplications affect an organism's ability to function and fight off cancer. **Stability and Change** • Mutations are changes in DNA when it is replicated. These changes can either increase stability through new adaptations or result in instability through cancer cells.

	Mutations can either be beneficial new traits or become cancer cells.	

Connections to Nature of Science
Science searches for cause-and-effect relationships to explain natural events.
Slower cellular replication processes lead to decreased likelihood of mutations.
Science Addresses Questions About the Natural and Material World
Students explore questions about cancer in organism other than humans.
Scientific Knowledge Assumes an Order and Consistency in Natural Systems
Students can infer that other large animals with slow replication processes also have smaller chances of getting cancer.

Possible Preconceptions/Misconceptions:
Since whales have more cells than humans, there is a higher chance for a whale's cell to malfunction and result in cancer.
More cells = more chances for cancer

LESSON PLAN – 5-E Model

ENGAGE: The lesson will start with proposing this scenario and question to students, 'One chef has three hours to cook a meal while a second chef has 45 minutes to cook the same exact meal. Which chef is going to execute the recipe better and why?'. Students would have three minutes to brainstorm individually and then would partner up to discuss. The teacher may prompt students to think about cooking competition shows. As partners students would have three more minutes to come up with the final answer and reasoning. Potential answers could include that the chef with three hours would execute the meal better because they could take their time. Another could be the Chef with 45 minutes would have to rush and in rushing would probably make mistakes. Then the teacher places one side of the room a sign with the label 45-minute chef and then put a sign on the other side of the room with the label: three-hour chef. The teacher would then explain to the class to walk to the side with the chef that you think would execute the meal better. Once students go to their perspective sides, the teacher will ask for volunteers to explain why they chose their answer. Hopefully, all students will walk to the side of the three-hour chef. If there are students on both sides, the teacher can allow for three minutes for debate. After, the teacher will have students return to their seats and propose a second scenario by prompting, "Now imagine when each chef finishes, they must start again with no break. They will have to repeat this process repeatedly until they can't. Which chef do you think can keep this up the longest with the least number of mistakes?". Students will again have three minutes to brainstorm independently. Then they will partner up, this time with a different partner and have three minutes to determine an answer with reasons why. The teacher will then instruct students to walk to the side of the room of the chef that they think will last the longest. They will repeat the same process as the first scenario, explaining and arguing for their choices. Then students will return to their seats

The teacher will then mention something along the lines of *how this connects to what we have been learning in class with cellular replication (or heredity or evolution)* depending on what the teacher is currently covering in class. Students will then have five minutes to jot down their thoughts into their science notebooks in the journal section if their notebooks are divided into a notes section and a journal/lab section. The teacher will then explain, that in the next class students will be reading a science journal that will allow them to make connections. Before class is over students will be instructed to fill out a one sentence summary of the class before they leave. In a one sentence summary students are required to explain the class and its importance. They can do this on a piece of loose-leaf paper cut in half, and hand it in as they leave the class.

EXPLORE: Review the verdict of yesterday's discussion and how doing something quickly often results in mistakes. Then the teacher will hand out the article *Why Don't Whales Get Cancer* (Tollis et al., 2024) and a graphic organizer, Science Journal Reading Chart (Figure 1). While reading, students are instructed to fill out the chart which highlights vocabulary, structure and function, and stability and change, and provides at least one example for each section. Student will have 30 minutes to read and fill out the chart. During this time the teacher should circulate around the room and remind students that they should fill out the chart while reading, not at the end.

EXPLAIN: After students read the article and fill out the Science Journal Reading Chart, they will be placed into groups of four. In their groups, they will compare their charts to one another's. They need to identify two similarities that are in all four charts and four differences. They will list their two similarities and four differences on the back of their charts. This will go to the end of the class period. To start the next class, each group will explain to the class their two similarities and four differences. This should take approximately three to five minutes per group, and total time will depend on the class size. For a class of 16 students, it should take approximately 12-15 minutes. After each group goes, have students answer one through four of the *Check your Understanding* questions from the article (Tollis et al., 2024).

1. What are gene mutations? What is an example of a positive outcome of a gene mutation? What about an example of a negative one?
2. Why do animals like whales have a lower likelihood of developing cancer?
3. What are large segmental duplications (LSDs), and what is their function?
4. Why did we think our actual genome size was shorter than our predicted genome size?

Here students will work independently and will be given 15 to 20 minutes to answer the questions. They are encouraged to check their Science Journal Reading Chart to see if any of their notes correspond to the understanding questions.

Closing: The teacher will then go over each question and explain each answer. As they are explaining each question, they should explicitly connect question one to stability and change and question three to function. Question one can be connected to stability and change because mutations are changes in DNA when it is replicated. These changes can either increase stability through new adaptations or result in instability through cancer cells. Question three can be connected to structure and function. The size and structure of large segmental duplications affect an organism's ability to fight off cancer. LSD's vary from species to species. Students will mark and correct their answers as the teacher goes through each one.

EVALUATE: On the first day of the lesson, students will be evaluated through their discussions and one sentence summary exit tickets. The teacher will start evaluating by listening to the class discussions about the two chef scenarios. Then, after class they will go through to see if students are on track or there are any misconceptions. They will bring up any misconceptions at the start of the second period during the review of the first day. During the second period of the lesson students will be evaluated during independent and group work. The teacher will wander the classroom listen for key words and discussions. While circulating, they can ask probing questions to make sure students are on track and clear up any potential misconceptions. During the second half of the third lesson, students will self-evaluate themselves by grading their own understanding questions.

As a final evaluation, on the fourth day, students will write a paragraph explaining how the article, *Why Don't Whales Get Cancer* (Tollis et al., 2024) relates to the original engagement scenario. When writing their paragraphs students will follow a claim, evidence, reasoning (CER) model (Figure 2). The CER will be used to evaluate students' abilities to make connections between phenomena, in this case cooking speed and cell replication speed. Students should use evidence from the article to support their claim. Students should then end their paragraph restating their claim.

EXTEND: A great part of the Science Journal for Kids/Teens library is that they always include in the conclusion how the journal can be related to the students' everyday lives. To extend the lesson, there will be an exit ticket with the questions "Will this information affect the decisions you make?". The question will be displayed on the board and a blank half sheet of paper will be handed out for the exit ticket. This will allow the teacher to assess them as engaged citizens using their understanding of science to better the world which is an aspect of scientific literacy.

In addition to this article, students will be assigned an article and understanding questions to read and complete for homework. They will be provided with a new Science Journal Reading Chart and are encouraged to fill it out while reading but are not required to do so. Students will continue to read science journals throughout the year. The goal is for them to use the comprehension skills practiced in this lesson as well as other new ones to strengthen their understanding of scientific literature.

SCIENCE JOURNAL READING CHART

Unfamiliar Vocabulary	Structure and Function	Stability and Change
List unfamiliar words and use context clues and others to create a simple definition	Identify structures of things in the article and explain how its shape affects its function.	How is the system changing over time and which factors are causing it to become unstable or more stable?
Mutations = mistakes in DNA or errors **Detect** = notice, discover, identify **Stability** = small disturbances will go away, the ability to return to a stable condition	**Blow hole** Opening and tube → allows for air flow	Belugas develop cancer cells at high rates → decrease their stability of life and population → factor is oil in nearby water

CLAIM, EVIDENCE, REASONING WORKSHEET

Name: _________________________ Date: _____________

CLAIM EVIDENCE REASONING

Claim	A sentence that answers the question. (1 sentence)
Evidence	Use information from the article and your prior knowledge of the world that supports your claim. (2-3 sentences)
Reasoning	Explain how the evidence supports your claim. Explain the importance. (2-3 sentences)
	Restate claim (1 sentence)

Question: How does the Chef scenario relate to the journal article, *Why Don't Whales Get Cancer* (Tollis et al., 2024)?

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APPENDIX F

5 E LESSON #5: ENERGY AND MATTER

5 E LESSON PLAN: ENERGY AND MATTER

Grade/ Grade Band: Middle School	**Topic: Sound and Energy**	Two 45-minute periods

Brief Lesson Description: This lesson is designed to add to a unit on energy and its forms. The lesson focuses on sound energy and how it is transferred from one medium to another. The core idea covered in this lesson is *Conservation of Energy and Energy Transfer*. The lesson also highlights Native American innovations in science which supports Indian Education For All. To start class, students will be introduced to the question, "What state of matter does sound travel the fastest?". Students will have time to brainstorm the question individually and then with classmates. Then, the teacher will tell a story about how Plains Indians used the knowledge of sound to track buffalo herds. The teacher will pose the question, *"How did Plains Indian camps differentiate between herds of buffalo and other camps (including enemy camps) on horseback?".* Students are instructed to develop and re-create possible sounds made by buffalo. They will record observations of the sound and useful inferences that they think American Indian Plains nations made. Then the teacher will explain potential observations. Students will be evaluated by their ability to explain *how energy is transferred from place to place through sound*. Students will be instructed to write a sentence (two sentences maximum) to explain this using evidence from the past two days.

Performance Expectation(s): Students will be able to make observations to provide evidence of the transfer of energy from place to place through sound.

Specific Learning Outcomes: Students will determine that sounds passes through solids better (can travel farther before dissipating) than gasses or liquids.

Narrative / Background Information

Prior Student Knowledge: Sound is a form of energy that is created by vibrations. It is a system that requires a force to create vibrations, a medium for vibrations to travel, and a receiver to hear the sound. Sound travels in waves. Intensity is used to describe volume.

Science & Engineering Practices:	**Disciplinary Core Ideas:**	**Crosscutting Concepts:**
Constructing explanations (for science) and designing solutions (for engineering) • Use various materials to replicate sounds of a buffalo herd • Using observations to create possible explanations that people would have made when tracking buffalo herds. **Engaging in Argument from Evidence** • Class discussions encourage students to question students' inferences and to defend their own. **Obtaining, Evaluating, and Communicate Info** • Collecting information from stories of buffalo herds • Class discussions	4-PS3-2: Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents. • Sound is created from a force, in this case hooves hitting the ground. • The energy from the force is converted into sound vibrations • Sound vibrations travel large distances in the ground • Sound vibrations also travel through the air. Energy is transferred from molecules to other adjacent molecules.	**Energy and Matter** • Sound energy in the form of waves travel differently through different matter. **Scale, Proportion and Quantity** • The intensity of vibrations helped determine estimated quantity of buffalo in a herd. • Hunters developed proportional estimates between distance and intensity of vibrations.

Connections to Nature of Science

Science is a way of knowing

All that American Indian Plains nations know about buffalo they discovered through science, specifically observing and making inferences about natural phenomena, as well as trial and error.

Science is a creative process

Students use their creativity to replicate the sound of hooves using random everyday materials.

Science is a Human Endeavor

Possible Preconceptions/Misconceptions:

Sound moves faster through air since gases have more energy typically than solids or liquids.

LESSON PLAN – 5-E Model

ENGAGE: To start class, students will be introduced to the question of "What state of matter does sound travel the fastest?". Students will have three minutes to brainstorm an answer with an explanation why. Then they will have three minutes to partner up and discuss the question. After the partner discussion, each group will share their thoughts. The teacher should preface the discussion by saying that we are just hearing each other's thoughts; I will not let you know if you are correct just yet. A misconception that may arise is that sound travels through a gas the fastest because gases have more energy than solids and liquids. Then the teacher would explain how Native Americans specifically the American Indian Plains nations have known the answer to this question for hundreds, maybe even thousands of years without any modern technology. They would use their scientific knowledge of sound to help them hunt buffalo (bison). The teacher would then explain how they would place their ear to the ground to hear and sense herds of buffalo that they cannot see. From this they could sense what direction herds were moving and estimate how far away they were. After explaining this phenomenon to students, have them rethink the original question. Give them three more minutes to decide which state of matter transmits sound best and have them use evidence from the story to support their claim. This can also be a time to introduce Indigenous language into the lesson. The teacher can share how to say buffalo (bison) in various Plains Indian languages for example in Blackfoot buffalo is iinnii which can be pronounced as ee-knee. The teacher will then call on three to four students to share their answer and their reasoning. The engage stage should take approximately 15 minutes.

Explanation of Phenomenon: hunters must use their knowledge of the natural world to track and hunt animals like the buffalo. Hearing is a key sense that they use to hunt and track, so they do not waste energy traveling all over the plains just looking for buffalo. They track buffalo that they cannot see by placing their ear to the ground to hear herds that are very far away. They do this because sound travels faster and farther in solids than they do in a gas. A main reason for this is that solid particles are closer together making it easier for sound to travel. Sound needs a medium to travel through. When it travels through a gas, like air, it must travel farther to reach a new medium, in this case an air particle. As it travels from medium to medium, the sound intensities weaken making it harder to hear sounds traveling through air that are far away.

EXPLORE: Students will explore the idea of listening to the ground deeper, by addressing a new issue: "How did Plains Indian camps differentiate between herds of buffalo and other camps (including enemy camps) on horseback?". Students are instructed to develop a list of possible observations of the sound and useful inferences that they think American Indian Plains nations made. Students will be put into groups to develop their list of Possible Ground Sound Observations and Inferences. Students will use knowledge from the teacher's initial explanation of the phenomena and materials from the engineering bin to come up with potential observations. The engineering bin is full of random items including blocks, rope, cups, string, marbles, pipe cleaners, etc. The directions for the activity will be listed on the board for students and are as follows

1. *Imagine what kind of sound an individual buffalo makes and what a herd of buffalo makes*
2. *Use materials from the engineering bin to replicate the sound of buffalo hooves.*
3. *Describe three different possible observations that hunters would hear when listening to the ground.*

4. *Hypothesize an inference for each observation that the hunters would most likely make.* Students will have 30 minutes, or until the end of class to test potential sounds and fill out their worksheet. During this time the teacher will circulate around the class and ask questions about student thought processes, and ask them again how might they know or can they know the difference between a herd of buffalo and an enemy camp on horseback because that information would be extremely important for survival.
EXPLAIN: During the following class the students will have a chance to explain their observations and inferences. The teacher will ask volunteers to share one of their observations and inferences. Each time a student shares one, the teacher would ask the class to raise their hand if they had a similar observation. Then they could ask those students if their inference based on that observation was the same as the classmate that shared. The hope is to hear five to six observations, which should take approximately 20 minutes to discuss. Closing: When students finish sharing, the teacher will then explain a few potential observations and useful inferences from them. One is the intensity of the vibrations. If the intensity of the sound and vibrations are faint, one can infer that they are very far away. If the intensity of the vibrations is very loud or they can feel large vibrations, one can infer that the herd is relatively close even though they cannot be seen, or that the herd is very large. Another observation could be that the way intensity fluctuates could be a signal of the herd changing directions.
EVALUATE: After the teacher explains potential observations, students will be evaluated by their ability to explain How energy is transferred from place to place through sound. Students will be instructed to write a sentence (two sentences maximum) to explain this, using evidence from the past two days. The question will be written on the board and students will answer and hand it in before they leave class. Students will have five minutes to answer the question. Students were also evaluated throughout the lesson during whole class discussions and when the teacher circulated the room during the explore segment of the lesson.
EXTEND: This lesson connects to scientific literacy through observing the natural world and using our knowledge of energy, matter, scale, proportion, and quantity to better understand it. To extend and wrap up the lesson, the teacher can have students write a paragraph or two explaining how Native knowledge is an example of scientific literacy. Before having students start, provide them with a simple definition of scientific literacy. There are many definitions, but a simple one that can be used is one's ability to observe and inquire about phenomena to better understand life and the world and engage in it.

POSSIBLE GROUND SOUND OBSERVATIONS AND INFERENCES

Name: ______________________ Partners: __________________________

Directions: Use materials from the engineering bin to speculate potential sounds and observations that hunters may make when pressing their ear to the ground. Then create an inference for each observation. Fill out at least 3 observations and inferences.

Materials used	Potential Observation	Inference
	1.	
	2.	
	3.	
	4.	

APPENDIX G:

SAMPLE PRESENTATION FOR LESSON 1

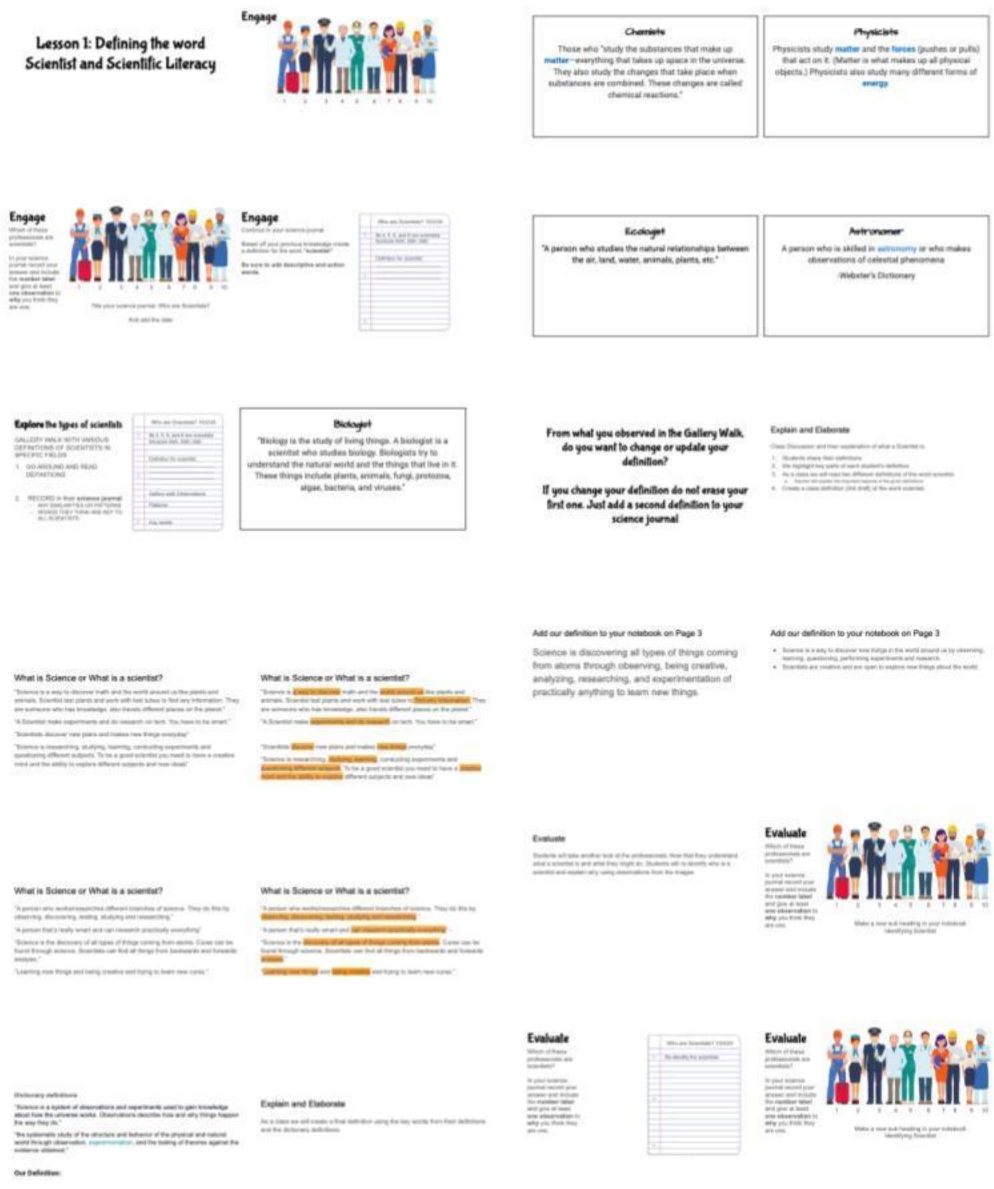

Figure 9: Example lesson for using the 5E lesson: defining a scientist