Stanford NGSS Integrated Curriculum

An Exploration of a Multidimensional World

UNIT 1

Colossal Collisions

What are the effects of an asteroid collision and how can we prevent a future one?

SCALE

Stanford Center for Assessment, Learning & Equity

Stanford NGSS Integrated Curriculum: An Exploration of a Multidimensional World
Unit 1: Colossal Collisions

Essential Question: What are the effects of an asteroid collision and how can we prevent a future one?

Total Number of Instructional Days: 29.5 – 30.5

Lift-Off Task: Asteroid Collisions	**Task 1:** An Ancient Collision	**Task 2:** Contact Forces	**Task 3:** Gravity – A Non-Contact Force

Connect to the Culminating Project using the Project Organizer

Group Culminating Project:
Create a video news segment describing a plan to prevent an asteroid collision.

Individual Culminating Project
Write a news article detailing the science behind plans to prevent an asteroid collision.

Unit 1 Pop-Out
What is a Scientist?
(*Implement after project*)

Storyline for Unit 1

It is largely believed that about 65 million years ago, a large asteroid collided with Earth, causing a huge explosion and a cascade of worldwide effects—the most well-known effect being the extinction of dinosaurs from our planet. In the Lift-Off Task, students are introduced to the phenomenon of this historical asteroid collision and asked to generate a list of questions they would ask in order to learn more. As they explore these questions throughout the unit, students will begin to conceptualize the potential impacts of an asteroid collision and start to envision what kinds of solutions they could use to prevent another large-scale collision with Earth, which is their culminating project for this unit.

In order to gather more information for their culminating project, students first need to investigate evidence that a collision of this magnitude has indeed happened before and find out what the effects were. In Task 1, students analyze different pieces of evidence that document the existence, diversity, extinction, and change of life forms on Earth due to a major asteroid collision that occurred 65 million years ago. By gathering this evidence, students will be able to explain to the public why it is so important that they do everything they can to prevent something like this happening again.

However, to prevent another asteroid collision, they need to learn more about the scientific concepts of forces and motion that they will use to do so. In Task 2, students investigate what factors affect the motion of objects and use this knowledge to help prevent a collision. By planning and carrying out their own investigations with everyday materials, students can leverage their experiential knowledge of objects in motion and begin to ascribe scientific concepts to these experiences. By the end of this task, students will be able to understand an asteroid's collision with Earth within the context of mass, forces, and motion, and use this new knowledge to brainstorm ideas on deflecting the asteroid.

In Task 3, students explore another, less tangible force that also affects how objects move and collide—gravity. In this task, students collect information from multiple resources to find that gravity does not just attract objects towards Earth, but also towards other bodies, and that this attraction has everything to do with an object's mass. By the end of this task, students will be able to dispel some common misconceptions about gravity and use their new understanding to brainstorm more ways to prevent the asteroid collision with Earth.

Once students are complete with all tasks, they begin to develop plans to thwart the impending asteroid collision with Earth. Once each group makes a decision on what their solution to save Earth is, each group will create a video news segment that describes how they plan to prevent this impending collision. As individuals, they will then write a detailed news article for people who want to know more about asteroid collisions with Earth and the science behind making this decision.

8th Grade Science Unit 1: Colossal Collisions
Unit Overview

Three-Dimensional Breakdown of the Performance Expectations

This unit was developed to align with, teach, and assess students' understanding and skills related to these Performance Expectations. Below, we have mapped out the disciplinary core ideas, crosscutting concepts, and science and engineering practices addressed in this unit. Aspects of the dimensions that are not explicitly addressed in this unit are crossed out.

Performance Expectations	Scientific and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
MS-LS4-1. Analyze and interpret data for patterns in the fossil record that document the existence, diversity, extinction, and change of life forms throughout the history of life on Earth under the assumption that natural laws operate today as in the past. [Clarification Statement: Emphasis is on finding patterns of changes in the level of complexity of anatomical structures in organisms and the chronological order of fossil appearance in the rock layers.] [Assessment Boundary: Assessment does not include the names of individual species or geological eras in the fossil record.]	**Analyzing and Interpreting Data** • Analyze and interpret data to determine similarities and differences in findings.	**LS4.A: Evidence of Common Ancestry and Diversity** • The collection of fossils and their placement in chronological order (e.g., through the location of the sedimentary layers in which they are found or through radioactive dating) is known as the fossil record. It documents the existence, diversity, extinction, and change of many life forms throughout the history of life on Earth.	**Patterns** • Graphs, charts, and images can be used to identify patterns in data.
MS-PS2-2. **Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object**. [Clarification Statement: Emphasis is on balanced (Newton's First Law) and unbalanced forces in a system, qualitative comparisons of forces, mass and changes in motion (Newton's Second Law), frame of reference, and specification of units.] [Assessment Boundary: Assessment is limited to forces and changes in motion in one-dimension in an inertial reference frame and to change in one variable at a time. Assessment does not include the use of trigonometry.]	**Planning and Carrying Out Investigations** • Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim.	**PS2.A: Forces and Motion** • The motion of an object is determined by the sum of the forces acting on it; if the total force on the object is not zero, its motion will change. The greater the mass of the object, the greater the force needed to achieve the same change in motion. For any given object, a larger force causes a larger change in motion. • ~~All positions of objects and the directions of forces and motions must be described in an arbitrarily chosen reference frame and arbitrarily chosen units of size. In order to share~~	**Stability and Change** • Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and forces at different scales.

		~~information with other people, these choices must also be shared.~~	
MS-PS2-1. Apply Newton's Third Law to design a solution to a problem involving the motion of two colliding objects.* [Clarification Statement: Examples of practical problems could include the impact of collisions between two cars, between a car and stationary objects, and between a meteor and a space vehicle.] [Assessment Boundary: Assessment is limited to vertical or horizontal interactions in one dimension.]	**Designing Solutions** • Apply scientific ideas or principles to design an object, tool, process or system.	**PS2.A: Forces and Motion** • For any pair of interacting objects, the force exerted by the first object on the second object is equal in strength to the force that the second object exerts on the first, but in the opposite direction (Newton's third law).	**Systems and System Models** • Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy and matter flows within systems.
MS-PS3-1. 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. [Clarification Statement: Emphasis is on descriptive relationships between kinetic energy and mass separately from kinetic energy and speed. Examples could include riding a bicycle at different speeds, rolling different sizes of rocks downhill, and getting hit by a wiffle ball versus a tennis ball.]	**Analyzing and Interpreting Data** • Construct and interpret graphical displays of data to identify linear and nonlinear relationships.	**PS3.A: Definitions of Energy** • Motion energy is properly called kinetic energy; it is proportional to the mass of the moving object and grows with the square of its speed.	**Scale, Proportion, and Quantity** • Proportional relationships (e.g. speed as the ratio of distance traveled to time taken) among different types of quantities provide information about the magnitude of properties and processes.
MS-PS2-4. Construct and present arguments using evidence to support the claim that gravitational interactions are attractive and depend on the masses of interacting objects. [Clarification Statement: Examples of evidence for arguments could include data generated from simulations or digital tools; and charts displaying mass, strength of interaction, distance from the Sun, and orbital periods of objects within the solar system.] [Assessment Boundary: Assessment does not include	**Engaging in Argument from Evidence** • Construct and present oral and written arguments supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem.	**PS2.B: Types of Interactions** • Gravitational forces are always attractive. There is a gravitational force between any two masses, but it is very small except when one or both of the objects have large mass—e.g., Earth and the sun.	**Systems and System Models** • Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy and matter flows within systems.

Newton's Law of Gravitation or Kepler's Laws.			
MS-ETS1-1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.	**Asking Questions and Defining Problems** • Define a design problem that can be solved through the development of an object, tool, process or system and includes multiple criteria and constraints, including scientific knowledge that may limit possible solutions.	**ETS1.A: Defining and Delimiting Engineering Problems** • The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that are likely to limit possible solutions.	**No CCC listed**
MS-ETS1-2. Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.	**Engaging in Argument from Evidence** • Evaluate competing design solutions based on jointly developed and agreed-upon design criteria.	**ETS1.B: Developing Possible Solutions** • There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem.	**No CCC listed**
MS-ETS1-3. Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.	**Analyzing and Interpreting Data** • Analyze and interpret data to determine similarities and differences in findings.	**ETS1.B: Developing Possible Solutions** • There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem. • Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors. **ETS1.C: Optimizing the Design Solution** • Although one design may not perform the best across all tests, identifying the characteristics of the	**No CCC listed**

		design that performed the best in each test can provide useful information for the redesign process—that is, some of those characteristics may be incorporated into the new design.	
MS-ETS1-4. Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.	**Developing and Using Models** • Develop a model to generate data to test ideas about designed systems, including those representing inputs and outputs.	**ETS1.B: Developing Possible Solutions** • A solution needs to be tested, and then modified on the basis of the test results, in order to improve it. • Models of all kinds are important for testing solutions. **ETS1.C: Optimizing the Design Solution** • The iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution.	**No CCC listed**

8th Grade Science Unit 1: Colossal Collisions
Unit Overview

Connections to Common Core Math and ELA Standards:

Over the course of this unit, students will gain knowledge and skills in science, as well as in math and English-language arts. Below we list the Common Core ELA and Math standards for middle school and 8th grade that are relevant to the curriculum tasks in this unit. Within the curriculum, there are opportunities to incorporate components of the following ELA and Math Standards:

Middle School Common Core ELA Standards		Unit Task
Key Ideas and Details	CCSS.ELA-Literacy.RST.6-8.1: Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions.	Task 1 Task 3 Culminating Project
	CCSS.ELA-Literacy. RST. 6-8.3: Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.	Task 2 Task 3 Culminating Project
Integration of Knowledge and Ideas	CCSS.ELA-Literacy.RST.6-8.9: Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).	Task 1 Culminating Project
	CCSS.ELA-Literacy.RST.6-8.9: Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic.	Task 1 Task 3
Text Types and Purposes	CCSS.ELA-Literacy.WHST.6-8.1: Write arguments focused on discipline content.	Task 3
Research to Build and Present Knowledge	CCSS.ELA-Literacy.WHST.6-8.8: Gather relevant information from multiple print and digital sources, using search terms effectively; assess the credibility and accuracy of each source; and quote or paraphrase the data and conclusions of others while avoiding plagiarism and following a standard format for citation.	Task 1 Task 3 Culminating Project
	CCSS.ELA-Literacy.WHST.6-8.9: Draw evidence from informational texts to support analysis, reflection, and research.	Task 1 Culminating Project

Middle School and 8th Grade Common Core Math Standards		Unit Task
Mathematical Practice	CCSS.MATH.MP.2: Reason abstractly and quantitatively.	Task 2 Task 3 Culminating Project

Connections to English Language Development (ELD) Standards:

We acknowledge that language development is a key component of disciplinary understanding and helps to support more rigorous and equitable outcomes for diverse students. This curriculum thus takes into account both the receptive and productive language demands of the culminating projects and strives to increase accessibility by including scaffolds for language development and pedagogical strategies throughout learning tasks. We aim to support language acquisition through the development of concept maps; utilizing sentence frames; implementing the Critique, Correct, Clarify technique; employing the Stronger Clearer strategy; and fostering large and small group discussions.

The California ELD Standards are comprised of two sections: the standards and a rubric. Outlined below are the standards from Section One that are met within this curriculum. For additional information, please refer to: https://www.pausd.org/sites/default/files/pdf-faqs/attachments/SS_ELD_8.pdf.

Eighth Grade ELD Standards		
Part I: Interacting in Meaningful Ways	A: Collaborative	1.Exchanging information and ideas with others through oral collaborative discussions on a range of social and academic topics
		2. Interacting with others in written English in various communicative forms (print, communicative technology, and multimedia)
		3. Offering and justifying options, negotiating with and persuading others in communicative exchanges
		4. Adapting language choices to various contexts (based on task, purpose, audience, and text type)
	B: Interpretive	5. Listening actively to spoken English in a range of social and academic contexts
		6. Reading closely literary and informational texts and viewing multimedia to determine how meaning is conveyed explicitly and implicitly through language
		7. Evaluating how well writers and speakers use language to support ideas and arguments with details or evidence depending on modality, text type, purpose, audience, topic, and content area
		8. Analyze how writers and speakers use vocabulary and other language resources for specific purposes (to explain, persuade, entertain, etc.) depending on modality, text type, purpose, audience, topic, and content area
	C: Productive	9. Expressing information and ideas in formal oral presentations on academic topics
		10. Writing literary and informational texts to present, describe, and explain ideas and information, using appropriate technology
		11. Justifying own arguments and evaluating others' arguments in writing
		12. Selecting and applying varied and precise vocabulary and other language resources to effectively convey ideas

<table>
<tr><td rowspan="7">Part II: Learning About How English Works</td><td rowspan="2">A: Structuring Cohesive Texts</td><td>1. Understanding text structure</td></tr>
<tr><td>2. Understanding cohesion</td></tr>
<tr><td rowspan="3">B: Expanding and Enriching Ideas</td><td>3. Using verbs and verb phrases</td></tr>
<tr><td>4. Using nouns and noun phrases</td></tr>
<tr><td>5. Modifying to add details</td></tr>
<tr><td rowspan="2">C: Connecting and Condensing Ideas</td><td>6. Connecting ideas</td></tr>
<tr><td>7. Condensing ideas</td></tr>
</table>

Connections to Environmental Awareness:

Over the course of this curriculum, students will explore content related to various environmental principles and concepts that examine the interactions and interdependence of human societies and natural systems. In accordance with the *Education and the Environment Initiative (EEI),* tasks throughout this curriculum explore many of *California's Approved Environmental Principles and Concepts.*

While this unit focuses on how a natural disaster can affect natural systems, it does not explicitly examine the interactions of *humans* and natural systems. In later units, we will outline the EEI principles relevant to the unit in this section of the unit overview.

8th Grade Science Unit 1: Colossal Collisions
Teacher Materials List

<u>Unit Essential Question</u>: *What are the effects of an asteroid collision and how can we prevent a future one?*

Overall Unit – All Tasks

- Unit 1, Task Cards Student Version, Lift-Off and Tasks 1 through 3
- Culminating Project Student Task Card
- Project Organizer
- Projector with Audio (for video or images, whenever needed)

Lift-Off Task (2 days)

Per Student

- Task Card Student Version: Lift-Off
- Post-Its (Optional)
- Task Card Student Version: Culminating Project
- Project Organizer

Per Group

- Poster paper and markers

Whole Class

- Poster paper and markers
- *See Instructions in Lift-Off for other optional materials to use for the class concept map

Task 1 (5 days)

Per Student

- Task Card Student Version: Task 1
- Project Organizer

Per Station

- Resource Cards 1 – 5 (2-3 copies per station)

Task 2 (5 days)

Per Student

- Task Card Student Version: Task 2
- Project Organizer

Per Group

- Stack of 40 pennies (Earth)
- Heavy marble or ball (asteroid *Etiam*)
- A track for *Etiam's* trajectory (pipe insulation tubing, cut in half lengthwise)
- Risers (4 textbooks)
- Ruler
- String
- Balls of varying mass (Recommended: http://www.arborsci.com/physics-balls, but if not, use marbles of different size and mass)
- Foam
- Rubberbands
- Popsicle sticks

- Plastic spoons
- Tape

Per Pair
- Tablets/Computers
- Headphones (Optional)

Whole Class
- Projector and Speakers

Task 3 (4-5 days)

Per Student
- Task Card Student Version: Task 3
- Project Organizer

Per Group
- Resource Cards 1-3 (1 copy of each per group)
- Computers or Tablets (1 per group)

Whole Class
- 2 shallow pans or trays with edges
- Sand (to fill pans with)
- Two balls of different mass, but same size (we recommend a Styrofoam or wood ball and a steel ball – see the following website for examples: http://www.arborsci.com/physics-balls)
- Projector and Speakers

Culminating Project (11 days)

Per Group: News Segment
- Same materials from Task 2 to run tests of all solutions
- Poster Paper or Computer Graphics Program (Ex: Google Drawing)
- Color pencils/pens or computer graphics
- Video camera or phone with recording capabilities
- Computers

Per Student: News Article
- Paper or Online platform for writing newspaper article
- Computers (Optional)

Unit 1 Pop-Out (2.5 days)

Per Student
- Student Version: Unit 1 Pop-Out
- Case Studies (Assigned By Group)

Per Group
- Presentation materials: computers OR posters and markers

8th Grade Science Unit 1: Colossal Collisions
Building on Prior Knowledge

This 8th grade integrated curriculum begins with a unit heavily focused on physical science and engineering and design components. In this unit, students begin to consider the factors that affect the motion of objects and use these ideas to inform their experience of collisions. In the culminating project for this unit, students will use the scientific knowledge and skills they gain throughout the unit and apply engineering and design principles to design a solution that can prevent an asteroid collision. These concepts are placed within a space science context—a context they will continue to explore in the next unit.

The integrated model requires students to access and use a wide range of ideas from prior grades. This content knowledge spans seven different Disciplinary Core Ideas: LS4.A. Evidence of Common Ancestry and Diversity, PS2.A. Forces and Motion, PS2.B. Types of Interactions, PS3.A. Definitions of Energy, ETS1.A. Defining and Delimiting Engineering Problems, ETS1.B Developing Possible Solutions, and ETS1.C. Optimizing the Design Solution.

As students explore these core ideas, they build on their skills in the following science and engineering practices: Asking Questions and Defining Problems, Planning and Carrying Out Investigations, Analyzing and Interpreting Data, Designing Solutions, and Engaging in Arguments with Evidence. In addition to science and engineering practices, students also continue to build on their knowledge of the following crosscutting concepts: Patterns; Scale, Proportion, and Quantity; Systems and System Models; and Stability and Change.

*This summary is based on information found in the NGSS Framework.

K-8 Progression of Disciplinary Core Ideas, Science and Engineering Practices, and Crosscutting Concepts for Unit 1

Disciplinary Core Ideas	K-2	3-5	6-8
LS4.A Evidence of Common Ancestry and Diversity	N/A	Some living organisms resemble organisms that once lived on Earth. Fossils provide evidence about the types of organisms and environments that existed long ago.	The fossil record documents the existence, diversity, extinction, and change of many life forms and their environments through Earth's history. The fossil record and comparisons of anatomical similarities between organisms enables the inference of lines of evolutionary descent.
PS2.A Forces and Motion	Pushes and pulls can have different strengths and directions, and can change the speed or direction of its motion or start or stop it.	The effect of unbalanced forces on an object results in a change of motion. Patterns of motion can be used to predict future motion. Some forces act through contact, some forces act even when the objects are not in contact. The gravitational force of Earth acting on an object near Earth's surface pulls that object toward the planet's center.	The role of the mass of an object must be qualitatively accounted for in any change of motion due to the application of a force.
PS2.B Types of Interactions			Forces that act at a distance involve fields that can be mapped by their relative strength and effect on an object.

PS3.A Definitions of Energy	N/A	Moving objects contain energy. The faster the object moves, the more energy it has. Energy can be moved from place to place by moving objects, or through sound, light, or electrical currents. Energy can be converted from one form to another form.	Kinetic energy can be distinguished from the various forms of potential energy. Energy changes to and from each type can be tracked through physical or chemical interactions. The relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter.
ETS1.A Defining and Delimiting Engineering Problems	A situation that people want to change or create can be approached as a problem to be solved through engineering. Such problems may have many acceptable solutions. Asking questions, making observations, and gathering information are helpful in thinking about problems. Before beginning to design a solution, it is important to clearly understand the problem.	Possible solutions to a problem are limited by available materials and resources (constraints). The success of a designed solution is determined by considering the desired features of a solution (criteria). Different proposals for solutions can be compared on the basis of how well each one meets the specified criteria for success or how well each takes the constraints into account.	The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that are likely to limit possible solutions.
ETS1.B Developing Possible Solutions	Designs can be conveyed through sketches, drawings, or physical models. These representations are useful in communicating ideas for a problem's solutions to other people.	Research on a problem should be carried out before beginning to design a solution. Testing a solution involves investigating how well it performs under a range of likely conditions. At whatever stage, communicating with peers about proposed solutions is an important part of the design process, and shared ideas can lead to improved designs. Tests are often designed to identify failure points or difficulties, which suggest the elements of the design that need to be improved.	A solution needs to be tested, and then modified on the basis of the test results, in order to improve it. There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem. Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors. Models of all kinds are important for testing solutions.
ETS1.C Optimizing the Design Solution	Because there is always more than one possible solution to a problem, it is useful to compare and test designs.	Different solutions need to be tested in order to determine which of them best solves the problem, given the criteria and the constraints.	Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process—that is, some of those characteristics may be incorporated into the new design. The iterative process of testing the most promising solutions and modifying what is

			proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution.

Science and Engineering Practices	K-2	3-5	6-8
Asking Questions and Defining Problems*	Asking questions and defining problems in K-2 builds on prior experiences and progresses to simple descriptive questions that can be tested. • Define a simple problem that can be solved through the development of a new or improved object or tool.	Asking questions and defining problems in 3-5 builds on prior experiences and progresses to specifying qualitative relationships. • Use prior knowledge to describe problems that can be solved. • Define a simple design problem that can be solved through the development of an object, tool, process, or system and includes several criteria for success and constraints on materials, time, or cost.	Asking questions and defining problems in 6-8 builds on prior experiences and progresses to specifying relationships between variables, and clarifying arguments and models. • Define a design problem that can be solved through the development of an object, tool, process, or system and includes multiple criteria and constraints, including scientific knowledge that may limit possible solutions.
Developing and Using Models*	Modeling in K–2 builds on prior experiences and progresses to include using and developing models (i.e., diagram, drawing, physical replica, diorama, dramatization, or storyboard) that represent concrete events or design solutions. • Develop and/or use a model to represent amounts, relationships, relative scales (bigger, smaller), and/or patterns in the natural and designed world(s).	Modeling in 3–5 builds on prior experiences and progresses to building and revising simple models and using models to represent events and design solutions. • Use a model to test cause and effect relationships or interactions concerning the functioning of a natural or designed system.	Modeling in 6–8 builds on prior experiences and progresses to developing, using, and revising models to describe, test, and predict more abstract phenomena and design systems. • Develop a model to generate data to test ideas about designed systems, including those representing inputs and outputs.

Planning and Carrying Out Investigations*	Planning and carrying out investigations in K-2 builds on prior experiences and progresses to simple investigations, based on fair tests, which provide data to support explanations or design solutions. • Plan and conduct an investigation collaboratively to produce data to serve as the basis for evidence to answer a question.	Planning and carrying out investigations in 3-5 builds on prior experiences and progresses to include investigations that control variables and provide evidence to support explanations or design solutions. • Plan and conduct an investigation collaboratively to produce data to serve as the basis for evidence, using fair tests in which variables are controlled and the number of trials considered.	Planning and carrying out investigations in 6-8 builds on prior experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or design solutions. • Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim.
Analyzing and Interpreting Data*	Analyzing data in K-2 builds on prior experiences and progresses to collecting, recording, and sharing observations. • Compare predictions (based on prior experiences) to what occurred (observable events).	Analyzing data in 3-5 builds on prior experiences and progresses to introducing quantitative approaches to collecting data and conducting multiple trials of qualitative observations. When possible and feasible, digital tools should be used. • Compare and contrast data collected by different groups in order to discuss similarities and differences in their findings. • Represent data in tables and/or various graphical.	Analyzing data in 6-8 builds on prior experiences and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis. • Analyze and interpret data to determine similarities and differences in findings.* • Construct and interpret graphical displays of data to identify linear and nonlinear relationships (*addressed in unit, not assessed in project)*.
Designing Solutions*	Designing solutions in K-2 builds on prior experiences and progresses to the use of evidence and ideas in designing solutions. • Generate and/or compare multiple solutions to a problem.	Designing solutions in 3-5 builds on prior experiences and progresses to the use of evidence in designing multiple solutions to design problems. • Apply scientific ideas to solve design problems.	Designing solutions in 6-8 builds on prior experiences and progresses to include designing solutions supported by multiple sources of evidence consistent with scientific knowledge, principles, and theories. • Apply scientific ideas or principles to design an object, tool, process or system.
Engaging in Argument from Evidence*	Engaging in argument from evidence in K-2 builds on prior experiences and progresses to comparing ideas and representations about	Engaging in argument from evidence in 3-5 builds on prior experiences and progresses to critiquing the scientific explanations or solutions proposed by peers by citing relevant evidence about the natural and designed world(s).	Engaging in argument from evidence in 6-8 builds on prior experiences and progresses to constructing a convincing argument that supports or refutes claims for either explanations or solutions about the natural and designed world(s). • Construct an oral and written argument

	the natural and designed world(s). • Construct an argument with evidence to support a claim. • Make a claim about the effectiveness of an object, tool, or solution that is supported by relevant evidence.	• Construct and/or support an argument with evidence, data, and/or a model. • Use data to evaluate claims about cause and effect. • Make a claim about the merit of a solution to a problem by citing relevant evidence about how it meets the criteria and constraints of the problem.	supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem. • Evaluate competing design solutions based on jointly developed and agreed-upon criteria.

*These SEPs are summatively assessed using the Culminating Project.

Crosscutting Concepts	K-2	3-5	6-8
Patterns*	Students recognize that patterns in the natural and human designed world can be observed, used to describe phenomena, and used as evidence. • Patterns in the natural and human designed world can be observed, used to describe phenomena, and used as evidence.	Students identify similarities and differences in order to sort and classify natural objects and designed products. They identify patterns related to time, including simple rates of change and cycles, and to use these patterns to make predictions. • Similarities and differences in patterns can be used to sort, classify, communicate and analyze simple rates of change for natural phenomena and designed products.	Students recognize that macroscopic patterns are related to the nature of microscopic and atomic-level structure. They identify patterns in rates of change and other numerical relationships that provide information about natural and human designed systems. They use patterns to identify cause and effect relationships, and use graphs and charts to identify patterns in data. • Graphs, charts, and images can be used to identify patterns in data.
Scale, Proportion, and Quantity*	Students use relative scales (e.g., bigger and smaller; hotter and colder; faster and slower) to describe objects. They use standard units to measure length. • Relative scales allow objects and events to be compared and described (e.g., bigger and smaller; hotter and colder; faster and slower).	Students recognize natural objects and observable phenomena exist from the very small to the immensely large. They use standard units to measure and describe physical quantities such as weight, time, temperature, and volume. • Natural objects and/or observable phenomena exist from the very small to the immensely large or from very short to very long time periods.	Students observe time, space, and energy phenomena at various scales using models to study systems that are too large or too small. They understand phenomena observed at one scale may not be observable at another scale, and the function of natural and designed systems may change with scale. They use proportional relationships (e.g., speed as the ratio of distance traveled to time taken) to gather information about the magnitude of properties and processes. They represent scientific relationships through the use of algebraic expressions and equations. • Proportional relationships (e.g., speed as the ratio of distance traveled to time taken) among different types of quantities provide information about

			the magnitude of properties and processes.
Systems and System Models*	Students understand objects and organisms can be described in terms of their parts; and systems in the natural and designed world have parts that work together. • Systems in the natural and designed world have parts that work together.	Students understand that a system is a group of related parts that make up a whole and can carry out functions its individual parts cannot. They can also describe a system in terms of its components and their interactions. • A system can be described in terms of its components and their interactions.	Students can understand that systems may interact with other systems; they may have sub-systems and be a part of larger complex systems. They can use models to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems. They can also learn that models are limited in that they only represent certain aspects of the system under study. • Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy and matter flows within systems.
Stability and Change	Students observe some things stay the same while other things change, and things may change slowly or rapidly. • Some things stay the same while other things change.	Students measure change in terms of differences over time, and observe that change may occur at different rates. Students learn some systems appear stable, but over long periods of time they will eventually change. • Change is measured in terms of differences over time and may occur at different rates.	Students explain stability and change in natural or designed systems by examining changes over time, and considering forces at different scales, including the atomic scale. Students learn changes in one part of a system might cause large changes in another part, systems in dynamic equilibrium are stable due to a balance of feedback mechanisms, and stability might be disturbed by either sudden events or gradual changes that accumulate over time. • Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and forces at different scales.

*These CCCs are summatively assessed using the Culminating Project.

Progression of Knowledge from Kindergarten - 8th Grade

LS4.A. Evidence of Common Ancestry and Diversity: Students do not engage with this DCI until the third grade. In third grade, students begin to ask the question: How are plants, animals, and environments of the past similar or different from current plants, animals, and environments? This gives students a first exposure to the fossil record and introduces them to the idea of the scale of Earth's long history, concepts that they will build on in the eighth grade unit. At this point, students only make isolated connections between organisms and their environment, comparing data between the past and the present. In this eighth grade unit, students attempt to form a much more cohesive and complex picture of the history of life on Earth. Thus, students move from a focus on Scale, Proportion, and Quantity in early grades to a focus on Patterns to organize the fossil record in later grades. In all grades, however, they are focusing on Analyzing and Interpreting Data as they look at the fossil record.

The following is the progression of the Performance Expectations for this DCI:

3-LS4-1 Analyze and interpret data from fossils to provide evidence of the organisms and the environments in which they lived long ago.

MS-LS4-1 Analyze and interpret data for patterns in the fossil record that document the existence, diversity, extinction, and change of life forms throughout the history of life on Earth under the assumption that natural laws operate today as in the past.

PS2.A. Forces and Motion: In Kindergarten through second grade, students engage with the foundational concepts within physics—that pushing or pulling on an object can change the speed or direction of its motion, or even more simply, can start or stop it. They also begin to explore the idea that pushes and pulls can have different strengths and directions. At this point, the concepts are all experiential. In third to fifth grade, the term force is introduced and students begin to define these experiences with more specificity and experiment accordingly. This provides a clear progression into this eighth grade unit, as students continue their investigations with motion, but define them even more specifically within Newton's laws of motion. As expected with this content, there is a heavy focus in all grades on Planning and Carrying Out Investigations and Analyzing and Interpreting the Data they produce. From Kindergarten – eighth grade, students are using the crosscutting concepts of Patterns to analyze data and Cause and Effect to explain the phenomena they observe. By the time they get to this eighth grade unit, students will be ready to apply these concepts and skills to design a solution related to forces and motion.

The following is the progression of the Performance Expectations for this DCI:

K-PS2-1 Plan and conduct an investigation to compare the effects of different strengths or different directions of pushes and pulls on the motion of an object.

K-PS2-2 Analyze data to determine if a design solution works as intended to change the speed or direction of an object with a push or a pull.

3-PS2-1 Plan and conduct an investigation to provide evidence of the effects of balanced and unbalanced forces on the motion of an object.

3-PS2-2 Make observations and/or measurements of an object's motion to provide evidence that a pattern can be used to predict future motion.

MS-PS2-2 Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object.

PS2.B. Types of Interactions: In Kindergarten to second grade, students observe through investigation that when objects touch or collide, they push on one another and can change motion—a crucial foundation to the project in this eighth grade unit. In third through fifth grade, students continue to investigate this phenomenon, but with the new vocabulary of balanced and unbalanced forces. This grade band also introduces other types of forces: electric and magnetic forces (which is not returned to in this eighth grade unit) and gravity. This prior knowledge of balanced and unbalanced forces and gravity sets the stage for this eighth grade unit as they work to develop their culminating project (preventing an asteroid collision). In eighth grade, students move beyond the concept of gravity as simply attracting objects towards Earth's center and consider how the mass of different objects might affect gravitational attraction. Throughout the grade levels, students focus on both Planning and Conducting Investigations to investigate these phenomena and also Engaging in Argument from Evidence in order to explain these phenomena. At all grade levels, students are building their ability to use Cause and Effect reasoning to explain these concepts.

The following is the progression of the Performance Expectations for this DCI:

K-PS2-1 Plan and conduct an investigation to compare the effects of different strengths or different directions of pushes and pulls on the motion of an object.

3-PS2-1 Plan and conduct an investigation to provide evidence of the effects of balanced and unbalanced forces on the motion of an object.

5-PS2-1 Support an argument that the gravitational force exerted by Earth on objects is directed down.

MS-PS2-1 Apply Newton's Third Law to design a solution to a problem involving the motion of two colliding objects.

MS-PS2-4 Construct and present arguments using evidence to support the claim that gravitational interactions are attractive and depend on the masses of interacting objects.

PS3.A. Definitions of Energy: Students do not engage with this DCI until the fourth grade. In third through fifth grade, students begin to connect motion with energy, asking questions like: What is energy and how is it related to motion? How is energy transferred? Because energy is a difficult concept for students to conceptualize at this age, these performance expectations deal mostly with experiential knowledge. By the end of this grade band, students will understand that the faster a given object is moving, the more energy it possesses, and if it collides with another object, it can transfer some of that energy in motion. This is crucial to this eighth grade unit, as students use these ideas to understand the science behind collisions and predict potential effects of an asteroid collision. While the fourth grade performance expectations focus on different science and engineering practices and crosscutting concepts than the eighth grade performance expectation for this unit, they all serve to prepare students for this level of content and application.

The following is the progression of the Performance Expectations for this DCI:

4-PS3-1 Use evidence to construct an explanation relating the speed of an object to the energy of that object.

4-PS3-3 Ask questions and predict outcomes about the changes in energy that occur when objects collide.

MS-PS3-1 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.

ETS1.A. Defining and Delimiting Engineering Problems: From Kindergarten to second grade, students first begin to approach situations as problems to be solved through engineering. They learn to ask questions and gather information to clearly understand a problem. In third through fifth grade, students build on understanding the problem to also identifying criteria and constraints surrounding the problem. In this eighth grade unit, students take this process a step further by defining criteria and constraints more precisely, including consideration of scientific principles and other relevant knowledge. In Kindergarten to second grade, students focus on the science and engineering practice of Asking Questions in order to help them with the practice of Defining Problems, which continues to be the main focus in subsequent grades.

The following is the progression of the Performance Expectations for this DCI:

K-2-ETS1-1 Ask questions, make observations, and gather information about a situation people want to change to define a simple problem that can be solved through the development of a new or improved object or tool.

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

MS-ETS1-1 Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

ETS1.B. Developing Possible Solutions: During Kindergarten through second grade, students begin communicating multiple designs in the form of diagrams and sketches. By third to fifth grade, students move from mere drawings to actually testing out their designs to see how they perform under different conditions. Students then use this data to make improvements. As in Kindergarten through second grade, students practice the idea that communication of designs with peers is an essential part of the design process. In this eighth grade unit, students move towards more systematic processes to evaluate solutions for how well they meet criteria and constraints. There is also a much greater emphasis on using the data to inform improvements, focusing on the idea that parts of different solutions can be used to make an even better solution. At the different grade levels, students engage in a variety of different science and engineering practices: Developing Models in K-2, Designing Solutions (specifically comparing solutions) in 3-5, and Engaging in Argument From Evidence in 6-8. This is representative of the different practices students are engaging with, described above.

The following is the progression of the Performance Expectations for this DCI:

K-2-ETS1-2 Develop a simple sketch, drawing, or physical model to illustrate how the shape of an object helps it function as needed to solve a given problem.

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

MS-ETS1-2 Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

ETS1.C. Optimizing the Design Solution: In Kindergarten to second grade, students begin to understand that because there are always multiple solutions to a problem, it is useful to compare and test designs. Students in third through fifth grade take this skill and use findings from those tests to determine which solution best meets criteria and constraints that they identified through ETS1.A. In accordance with the progression students follow in middle school for ETS1.B, students in this eighth grade unit move towards using data and analysis to identify best characteristics and inform a new and better solution. Thus, it makes sense that at all grade levels, students focus on Science and Engineering Practices related to testing and analyzing: Planning and Carrying Out Investigations and Analyzing and Interpreting Data. At the eighth grade level, students take these skills further to develop models that will generate data to test ideas about designed systems.

The following is the progression of the Performance Expectations for this DCI:

K-2-ETS1-3 Analyze data from tests of two objects designed to solve the same problem to compare the strengths and weaknesses of how each performs.

3-5-ETS1-3 Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

MS-ETS1-3 Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.

MS-ETS1-4 Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

8th Grade Science Unit 1: Colossal Collisions
Culminating Project

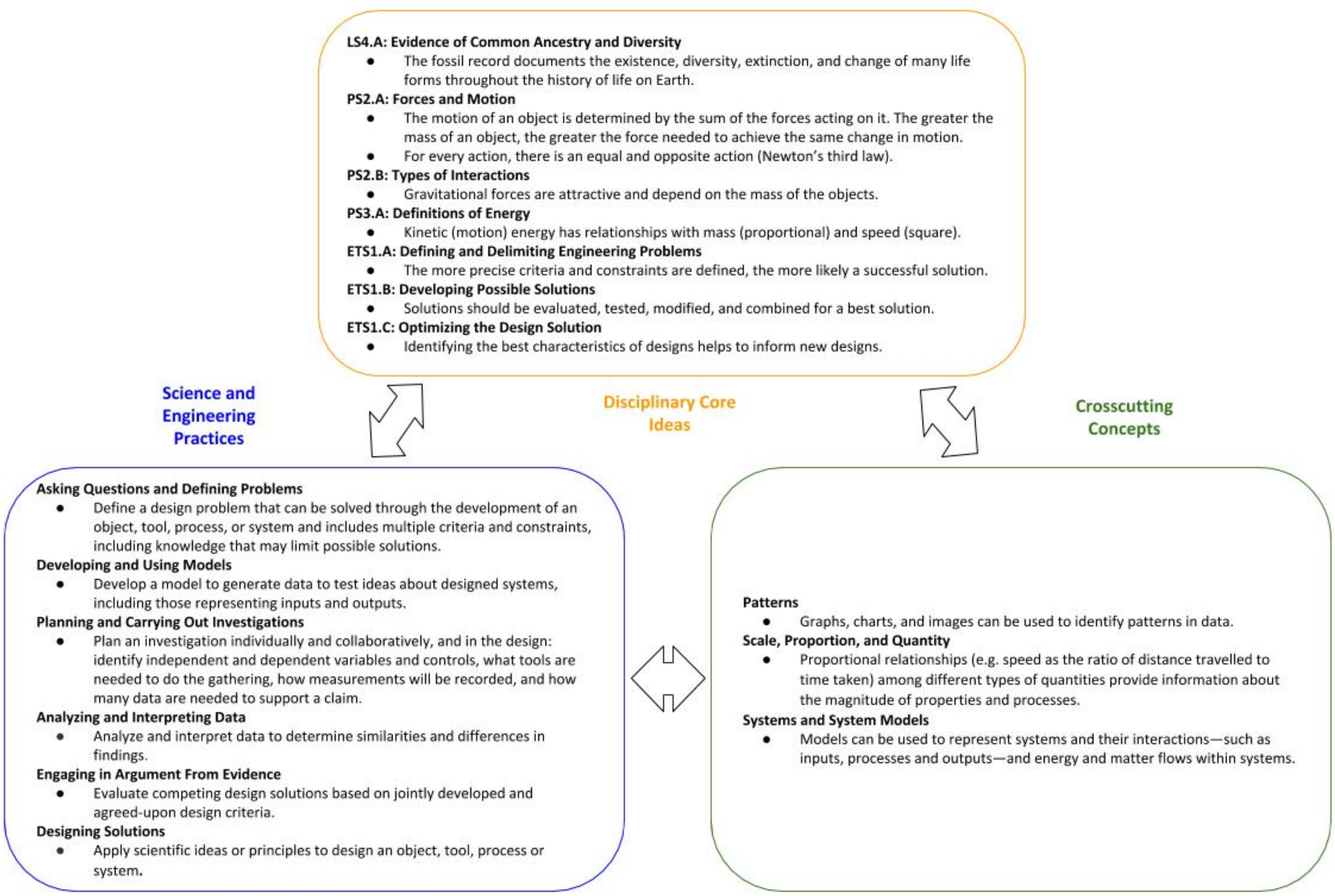
Unit Essential Question: *What are the effects of an asteroid collision and can we prevent a future one?*

Introduction

The area between Mars and Jupiter contains countless numbers of asteroids. This jostling asteroid belt orbits the sun and occasionally some asteroids slam into each other, knocking them out of regular orbit. This was the case for the asteroid that collided with Earth 65 million years ago—the phenomenon in the Lift-Off Task. In this unit's project, another one of these asteroids (called *Etiam*), a very large one that is capable of destroying most life on Earth, is headed our way.

This culminating project is a design problem that asks students to demonstrate all four of the Engineering Design Performance Expectations at the middle school level. In doing so, students will work together to thwart the impending collision of *Etiam* with Earth. There are many different solutions to this problem—each one has its own challenges and benefits. How they decide to protect the Earth will depend on decisions that their group makes using the information and concepts they develop over the course of this unit. Once each group makes a decision on what their solution to save Earth is, each group will create a video news segment that describes how they plan to prevent this impending collision. As individuals, they will then write a detailed news article for people who want to know more about asteroid collisions with Earth and the science behind making this decision.

3-Dimensional Assessment



8th Grade Science Unit 1: Colossal Collisions
Culminating Project

Time Needed (Based on 45-Minute Periods)
11 days at end of unit

- Group Project: 6 periods
    - Develop models of all possible design solutions (1 day)
    - Plan an experiment to test the design solutions (1 day)
    - Run experiment, collect data, and evaluate data (1 day)
    - Finalize solution and create news segment (2 days)
    - Presentation day (1 day)
- Individual Project: 5 periods
    - First draft: 3 periods
    - Feedback: 1 period
    - Revision: 1 period

Materials
News Segment

- Optional: Engineering and Design Process Graphic Organizer (provided at end of this teacher guide)
- Same materials from Task 2 to run tests of all solutions (Provide additional materials, as needed)
- Poster Paper or Computer Graphics Program (Ex: Google Drawing)
- Color pencils/pens or computer graphics
- Video camera or phone with recording capabilities
- Computers

News Article

- Optional: Newspaper Article Guide (provided at end of this teacher guide)
- Paper or Word Processing software for writing newspaper article
- Computers (Optional)

Instructions for the Culminating Project

1. Introduce the Culminating Project at the end of the Lift-Off task, including both group and individual components outlined in the Challenge.

2. Read over the Culminating Project Task Card with the students. We recommend only reading the Challenge, Background, and Group Project Criteria for Success at this time in order to not overwhelm students with information.
    - Take questions for clarification.
    - Make sure to emphasize the background data on the asteroid, *Etiam*, noting that students will need to return to this data and review it more thoroughly as they get closer to the project.
        - We recommend you draw a diagram of the trajectory of *Etiam* through space on the board, so students can visualize the context.

3. Remind students that as they go through the Project Organizer, they will be planning pieces of their design solution and recording scientific concepts they will likely need for their individual project. However, there is nothing wrong with going back and changing their ideas over the course of the unit. The students won't fully design their solution and news segment until the end of the unit, so change during the imaginative and creative time is acceptable and often experienced.

4. Make sure the students fill out the Project Organizer after each task, which will help students think about different parts of their solution along the way. This process allows students to both apply and document relevant scientific concepts as they move throughout the unit. This will inform both their group and individual projects.
    - We recommend that students complete the Project Organizer individually. They might discuss ideas first as a group, but should then respond individually. This allows students time to process concepts on their own and generate their own ideas, which can be used later when it comes to developing their group project.

5. The table below summarizes how the Project Organizer guides the students through developing different components of their design solution and corresponding news segment and news article.

Task	Project Organizer	Group and Individual Culminating Project
Lift Off Asteroid Collisions	• What do you already know about collisions? • What are some negative consequences? • What are some methods humans use to prevent every-day collisions?	• None
Task 1 An Ancient Collision	• What evidence is there that this has happened before? • What were the effects last time? • How will you use the evidence to convince the public that it is important to protect Earth from another asteroid collision?	• News article cites data from the fossil record as evidence of the effects of past asteroid collisions.
Task 2 Contact Forces	• How will *Etiam's* large mass affect Earth? Use experimental evidence as well as scientific ideas of mass, kinetic energy, and speed to back up your response. • How can Newton's laws help us predict what will happen when *Etiam* hits Earth? • Record ideas you have on deflecting *Etiam*, using the following questions to help you: In the experiments, which solutions worked best? Based on the data, can you combine characteristics from the best solutions to create an even better one? How does each solution use contact forces and your understanding of mass and motion?	• News segment proposes a solution to prevent a collision between *Etiam* and Earth. This solution may be related to any of Newton's laws. • News article compares the impact of a 2013 asteroid collision to the potential impact of the *Etiam* collision, using the relationships between mass, kinetic energy, and speed. Article also describes and diagrams solutions that use the science of Newton's three laws to deflect *Etiam.*
Task 3 Gravity—A Non-Contact Force	• How does gravity currently influence *Etiam*? • What other objects in the solar system might influence *Etiam* as it travels through space and why? • How can other gravitational forces affect the trajectory of *Etiam*?	• News segment proposes a solution to prevent a collision between *Etiam* and Earth. This solution may be related to gravity and mass. • News article describes and diagrams a solution that uses the concepts of gravity and mass to deflect *Etiam*.

6. After all the learning tasks are completed, and all the Project Organizers are completed, the students can start to design a potential solution to thwart the collision of Earth and *Etiam*.
    - We highly recommend providing students with the Engineering and Design Process Graphic Organizer to guide them through this process. This allows students to engage with all the middle school Engineering and Design Performance Expectations, which not only helps students to design the best possible solution but also helps them write a news article that better meets the criteria of their individual project.
    - Through this process, students are asked to develop models of all possible design solutions, plan and run an experiment to test the design solutions, collect and evaluate data, and then use the data to inform an improved design solution.

7. Students will then create a news segment that describes the situation to the public and explains why their chosen solution is the best option. Their news segment must meet all the criteria in the student handout. The Project Organizers should be used as reference for the students to remind them of all the components of the project.
    - As always, we recommend the use of group roles for Culminating Project work time (See "How to Use This Curriculum" for details). We recommend changing the roles every work day.

8. Below are some possible strategies to stop the collision of *Etiam* and Earth (although students may come up with others).
    - Blow up *Etiam* before it gets near the Earth so that not all pieces will come into contact with the Earth. Pieces with less mass will thus impact the Earth with less force.
    - Use the gravity of another large object to change *Etiam's* trajectory.
        - Ex: Use the Moon to intercept *Etiam* so that the Earth will be saved.
    - Build a large cushion for *Etiam* to hit on Earth, preventing *Etiam* from doing too much damage on Earth.

9. Optional: Have groups show their news segment as a class. This is not only an opportunity for students to showcase their hard work, but also a time for students to see other solutions before they do their individual project.

10. Once the news segments are complete, students are ready to move on to their individual project. Students will create a news article for people who want to know more about asteroid collisions with Earth and the science behind making this decision. This should meet all the criteria in the student handout. You may wish to provide students with a guide to help them structure their article. An option is provided at the end of this teacher guide.

11. Conduct a peer review of the News Article after students have completed a first draft.
    - Copy the News Article Peer Review Feedback form found in the Student Instructions. Another option is to use the Student 3-Dimensional Individual Project Rubric.
    - Assign each student a partner, preferably a partner from a different group.
    - Students switch drafts and assess them using the peer review feedback form or 3-Dimensional Rubric.
        - Remind each student to give one positive comment and one constructive comment for each section on the checklist.

  - Allow students time to present their feedback to their partner, so their partner may ask clarifying questions if needed.

12. After receiving feedback, allow students time to complete a final draft based on the feedback they received.

Assessment

The Project Organizer can be formatively assessed using:

- *Criteria of your choice.* We recommend using the 3-Dimensional Assessment matrix from the Unit Overview to inform your criteria.

The Group Culminating Project will be summatively assessed using:

- The *Group Project Criteria for Success* Checklist

The Individual Culminating Project will be summatively assessed using:

- The *3-Dimensional Individual Project Rubric*.
- Keep in mind that the Proficient level indicates that the student has successfully demonstrated understanding of the criteria. Because we are in the early stages of NGSS adoption, it may take multiple opportunities throughout the course of the year for students to reach Proficient.
- If you wish to give students a numeric score, you could take the average score of all of their rubrics or add up rubric scores to give students a summation out of the total. Because of the note above, this scoring may not correlate to traditional grading systems.
- While we recommend scoring all of the project criteria with the rubrics for each student, we understand the burden of that level of scoring.
  - One option is to select the rubrics that you wish to focus on for this project and use those to assess each student's individual project. For example, in this unit you may wish to assess students on Engineering and Design and thus would just focus on the rubrics pertaining to the Engineering and Design PEs.
  - Another option is to review the Proficient level of each of the project's rubrics and use the descriptions to generally analyze all student work for trends.

Engineering and Design Process Graphic Organizer

Step 1: Develop models of all possible solutions

- Draw a model of each possible design solution below. You will use these models to generate data as you test all the solutions. In your models, label the materials you will use for the different parts.

Design Solution 1	Design Solution 2
Design Solution 3	Design Solution 4

Step 2: Plan an experiment to test all your solutions

Identify the Independent Variable: What are you changing each time you run the experiment?	Identify the Dependent Variable: What will you measure or observe at the end of the experiment to see how successful the design is?	Identify the Controls: What should you keep the same so that you only measure what you want to?

8^{th} Grade Science Unit 1: Colossal Collisions
Culminating Project

Lab Set-Up: Draw and describe below:

Materials

-
-
-
-
-
-
-
-
-
-

Procedure

1.
2.
3.
4.
5.
6.

Step 3: Run experiment and collect data

Data Table

- Complete the data table below or draw a new one to record your data, including any observations. You should run multiple trials for each of the design solutions.

	Dependent Variable: ______________________________			Other Observations
	Trial 1	Trial 2	Trial 3	
Design Solution 1				
Design Solution 2				
Design Solution 3				
Design Solution 4				

Step 4: Evaluate the data and use to inform your final design solution

1. According to the test data, how well did each design meet the criteria of the problem?
   - Design Solution 1:
   - Design Solution 2:
   - Design Solution 3:
   - Design Solution 4:
2. What are the best characteristics of each design solution and how can you combine them into one improved solution?

8th Grade Science Unit 1: Colossal Collisions
Culminating Project

<u>Optional Guide for Article</u>: *This guide serves as both a guide for the article's structure as well as a reminder of what students should include in their individual project. However, this does <u>not</u> replace the Individual Project Criteria for Success and both documents should be used in conjunction. This is best used as a digital template, so students can replace the wording, but you may also make hard copies to serve as guidelines if students are writing their articles by hand.*

News Article Title

1-2 catchy sentences summarizing your article.

By YOUR NAME Month, ##, 20##

____

NAME OF YOUR CITY – In this paragraph, explain the problem of how *Etiam* is on a trajectory to hit the Earth. Use the *Individual Project Criteria for Success Checklist* to make sure you include all parts.

In these next two paragraphs, convince your audience why it is important we protect Earth from an asteroid collision. One paragraph should cite data from the fossil record and the next paragraph should compare *Etiam* to *Chelyabinsk*. Use the *Individual Project Criteria for Success Checklist* to make sure you include all parts.

Fig 1. ________________	Fig 2. ________________	Fig 3. ________________	Fig 4. ________________
______________________	______________________	______________________	______________________

In this next set of paragraphs, describe all possible solutions to the public, including the science concepts behind them. For each solution, draw a diagram in the spaces above. As you describe these diagrams in the paragraphs, you can refer to them by using figure numbers in parentheses. For example, "… (see Fig. 1)." Use the *Individual Project Criteria for Success Checklist* to make sure you include all parts.

In this next set of paragraphs, describe the experiment you ran and how you used the data to evaluate all the potential design solutions. Use the *Individual Project Criteria for Success Checklist* to make sure you include all parts.

In this paragraph, describe how you combined best characteristics of different designs in order to come up with the best solution to prevent a collision between *Etiam* and Earth. Use the *Individual Project Criteria for Success Checklist* to make sure you include all parts.

Draw a diagram and/or report calculations here for your final proposed solution.

End with a brief conclusion of 1-2 catchy sentences. You may wish to look at some online articles as samples to inspire ideas.

8th Grade Science Unit 1: Colossal Collisions
3-Dimensional Individual Project Rubric

Overview: The following rubrics can be used to assess the individual project: the News Article. Each rubric is aligned to one section of the *Individual Project Criteria for Success*, located on the Culminating Project Student Instructions. *If student provides no assessable evidence (e.g., "I don't know" or leaves answer blank), then that student response cannot be evaluated using the rubric and should be scored as a zero.

Below we provide an alignment table that details the dimensions assessed for each criterion.

	Student Criteria for Success	Disciplinary Core Idea	Science and Engineering Practice	Crosscutting Concept
1	❒ Explain the problem of how *Etiam* is on a trajectory to hit the Earth. ○ What are the criteria for success in solving this problem? ○ What constraints exist that limit possible solutions?	**ETS1.A: Defining and Delimiting Engineering Problems** • The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that are likely to limit possible solutions.	**Asking Questions and Defining Problems** • Define a design problem that can be solved through the development of an object, tool, process or system and includes multiple criteria and constraints, including scientific knowledge that may limit possible solutions.	N/A
2	❒ Cite data from the fossil record as evidence of past effects of asteroid collisions.	**LS4.A: Evidence of Common Ancestry and Diversity** • The collection of fossils and their placement in chronological order (e.g., through the location of the sedimentary layers in which they are found or through radioactive dating) is known as the fossil record. It documents the existence, diversity, extinction, and change of many life forms throughout the history of life on Earth.	**Analyzing and Interpreting Data** • Analyze and interpret data to determine similarities and differences in findings.	**Patterns** • Graphs, charts, and images can be used to identify patterns in data.
3	❒ The public is familiar with another recent asteroid collision from February 2013. An asteroid known as *Chelyabinsk*, hit Russia. Its mass was 10,000,000 or 1 x 10^7 kg and its speed was 60,000-69,000 km/hr. How can you compare the force of	**PS3.A: Definitions of Energy** • Motion energy is properly called kinetic energy; it is proportional to the mass of the moving object and grows with the square of its speed.	N/A	**Scale, Proportion, and Quantity** • Proportional relationships (e.g. speed as the ratio of distance traveled to time taken) among different

	Chelyabinsk's collision with the force of *Etiam*'s collision? Explain why the impact of one of these asteroids will be greater by describing the specific relationships between mass and kinetic energy and speed and kinetic energy.			types of quantities provide information about the magnitude of properties and processes.
4	❐ Describe and diagram all possible solutions for the public. These solutions must collectively use and explain all the following scientific concepts: ○ Gravity and mass	**PS2.B: Types of Interactions** • Gravitational forces are always attractive. There is a gravitational force between any two masses, but it is very small except when one or both of the objects have large mass—e.g., Earth and the sun.	N/A	**Systems and System Models** • Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy and matter flows within systems.
5	❐ Describe and diagram all possible solutions for the public. These solutions must collectively use and explain all the following scientific concepts: ○ Newton's first law ○ Newton's second law ○ Newton's third law	**PS2.A: Forces and Motion** • The motion of an object is determined by the sum of the forces acting on it; if the total force on the object is not zero, its motion will change. The greater the mass of the object, the greater the force needed to achieve the same change in motion. For any given object, a larger force causes a larger change in motion. • For any pair of interacting objects, the force exerted by the first object on the second object is equal in strength to the force that the second object exerts on the first, but in the opposite direction (Newton's third law).	**Developing and Using Models** • Develop a model to generate data to test ideas about designed systems, including those representing inputs and outputs.	N/A
6	❐ Explain the investigation of solutions: ○ Describe the experiment you ran to evaluate all the potential design solutions. Include: independent variable, dependent variable,	**ETS1.B: Developing Possible Solutions** • There are systematic processes for evaluating solutions with respect to how well they meet the criteria ~~and constraints~~ of a problem.	**Planning and Carrying Out Investigations** • Plan an investigation individually and collaboratively, and in the	N/A

	controls, procedure, and data collected. ○ Evaluate the different solutions: According to the test data, how well did each design meet the criteria of the problem?	• Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors. • A solution needs to be tested, and then modified on the basis of the test results, in order to improve it. • Models of all kinds are important for testing solutions.	design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim. **Engaging in Argument From Evidence** • Evaluate competing design solutions based on jointly developed and agreed-upon design criteria.	
7	❒ What is your final design solution to prevent a collision between *Etiam* and the Earth? ○ How did you combine best characteristics of different designs to come up with the best possible design? ○ Show diagram of final design solution (and any calculations, if applicable).	**ETS1.C: Optimizing the Design Solution** • Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process—that is, some of those characteristics may be incorporated into the new design. • The iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution.	**Designing Solutions** • Apply scientific ideas or principles to design an object, tool, process or system.	N/A

8th Grade Science Unit 1: Colossal Collisions
3-Dimensional Individual Project Rubric

Rubric 1: Student defines the problem of an asteroid collision, including criteria of success and constraints that might limit possible solutions.

- Dimensions Assessed: DCI – ETS1.A: Defining and Delimiting Engineering Problems, SEP – Asking Questions and Defining Problems

Emerging (1)	Developing (2)	Proficient (3)	Advanced (4)
Student **does not** define the problem of an asteroid collision **and/or** includes **inaccurate or irrelevant** criteria of success and constraints that might limit possible solutions.	Student **accurately** defines the problem of an asteroid collision, including **accurate** criteria of success **OR** constraints that might limit possible solutions.	Student **accurately** defines the problem of an asteroid collision, including **accurate, but partial** criteria of success **and** constraints that might limit possible solutions.	Student **accurately** defines the problem of an asteroid collision, including **accurate and complete** criteria of success and constraints that might limit possible solutions.
Look Fors: ● Student leaves out an explanation of the problem. ● And/or the student identifies criteria of success and constraints that are inaccurate or irrelevant. For example, they might identify a criterion of success as controlling the damage after the asteroid collision and a constraint as the ability to control the asteroid.	**Look Fors:** ● Student accurately explains that *Etiam's* collision with Earth would likely cause a huge impact on Earth systems and biodiversity. ● Student accurately defines at least one criteria for success OR at least one constraint. See right-hand columns for examples.	**Look Fors:** ● Student accurately explains that *Etiam's* collision with Earth would likely cause a huge impact on Earth systems and biodiversity. ● Student accurately defines a criterion for success. For example, completely preventing the collision. ● Student also accurately defines one constraint. For example, limited amount of time before the asteroid will hit Earth.	**Look Fors:** ● Student accurately explains that *Etiam's* collision with Earth would likely cause a huge impact on Earth systems and biodiversity. ● Student accurately and completely defines the criteria for success. For example, completely preventing the collision or minimizing the impact in a way that reduces effects on Earth. ● Student also accurately and completely defines any constraints. For example, limited amount and size of materials available, the technology available, limited amount of time available before the asteroid will hit Earth.

8th Grade Science Unit 1: Colossal Collisions

3-Dimensional Individual Project Rubric

Rubric 2: Student explains the importance of protecting Earth from an asteroid collision by citing similar patterns in the fossil record data as evidence.

- Dimensions Assessed: DCI – LS4.A: Evidence of Common Ancestry and Diversity, CCC – Patterns, SEP – Analyzing and Interpreting Data

Emerging (1)	Developing (2)	Proficient (3)	Advanced (4)
Student **irrelevantly** explains the importance of protecting Earth from an asteroid collision.	Student **accurately** explains the importance of protecting Earth from an asteroid collision but cites **no specific** patterns in the fossil record data as evidence.	Student **accurately** explains the importance of protecting Earth from an asteroid collision by citing **one** similar pattern in the fossil record data as evidence.	Student **accurately** explains the importance of protecting Earth from an asteroid collision by citing **multiple** similar patterns in the fossil record data as evidence.
Look Fors: • Student provides an irrelevant explanation of why preventing an asteroid collision is important. For example, "It is important we prevent an asteroid collision because they are bad for the environment." • Any fossil record evidence is thus not relevant to the claim.	**Look Fors:** • Student provides a relevant explanation of importance. For example, "It is important we protect Earth from an asteroid collision because the past shows us that asteroid collisions can have large negative consequences for Earth and organisms." • Student does not cite specific data from the fossil record. For example, "When this happened before, lots of plants and animals died."	**Look Fors:** • Student provides a relevant explanation of importance. For example, "It is important we protect Earth from an asteroid collision because the past shows us that asteroid collisions can have large negative consequences for Earth and organisms." • Student provides one pattern in the fossil record from Task 1 as evidence. For example, "By observing the fossil record, scientists created a graph to show extinction rates. There have been several mass extinctions over time, one 65 million years ago that we know was caused by an asteroid collision. If we don't want another mass extinction, we must prevent *Etiam's* collision."	**Look Fors:** • Student provides a relevant explanation of importance. For example, "It is important we protect Earth from an asteroid collision because the past shows us that asteroid collisions can have large negative consequences for Earth and organisms." • Student provides multiple patterns in the fossil record from Task 1 as evidence. For example, "A layer of iridium (component of asteroids) shows that an asteroid hit 65 million years ago. The same soil layer also has a lot of soot, suggesting massive fires all over the world. Another graph and model made from the fossil record shows a large decrease in the number of marine species, as well as a decrease in leaf diversity at this time. If we don't want this all to happen to Earth again, we must prevent *Etiam's* collision."

8th Grade Science Unit 1: Colossal Collisions

3-Dimensional Individual Project Rubric

Rubric 3: Student describes the relationships between mass, kinetic energy, and speed, and uses these relationships to provide information about the potential magnitude of the *Etiam* collision.

- Dimensions Assessed: CCC – Scale, Proportion, and Quantity; DCI – PS3.A: Definitions of Energy

Emerging (1)	Developing (2)	Proficient (3)	Advanced (4)
Student describes **no** relationships between mass, kinetic energy, and speed, **and/or** uses relationships to provide **inaccurate** information about the potential magnitude of the *Etiam* collision.	Student describes **partial** relationships between mass, kinetic energy, and speed, and uses this relationship to provide **accurate** information about the potential magnitude of the *Etiam* collision.	Student describes **complete but general** relationships between mass, kinetic energy, and speed, and uses these relationships to provide accurate information about the potential magnitude of the *Etiam* collision.	Student describes complete **and specific** relationships between mass, kinetic energy, and speed, and uses these relationships to provide accurate information about the potential magnitude of the *Etiam* collision.
Look Fors: ● Student does not describe any relationships between mass, speed, and kinetic energy between *Etiam* and *Chelyabinsk.* For example, no data or general comparisons are described. ● And/or student compares the data for the asteroids *Etiam* and *Chelyabinsk* to form an inaccurate conclusion. For example, "*Etiam* will hit earth with about the same force as *Chelyabinsk.*"	**Look Fors:** ● Student accurately describes one of the relationships, but not both. See right-hand columns for accurate responses for each relationship. ● Student makes comparisons between the *Etiam* and *Chelyabinsk* data that are accurate and use one of the relationships. For example, "The mass of *Etiam* is 6.89 x 10^{15} kg, which is a much larger mass than *Chelyabinsk* at 1 x 10^{7} kg. Because the mass of *Etiam* is much larger, this means it will have much more kinetic energy and will hit Earth with much more force, causing more damage than *Chelyabinsk."*	**Look Fors:** ● Student accurately describes the relationships, but relationships are general: An object with more mass has more kinetic energy. An object moving at a greater speed will have more kinetic energy. ● Student makes comparisons between the *Etiam* and *Chelyabinsk* data that are accurate and use the relationships above. For example, "The mass of *Etiam* is a much larger mass than *Chelyabinsk*. Because the mass of *Etiam* is much larger, this means it will have much more kinetic energy. This is shown by its greater speed. This helps us predict that *Etiam* will have much more kinetic energy to transfer to Earth, causing more damage than *Chelyabinsk."*	**Look Fors:** ● Student accurately describes the specific relationships: Kinetic energy is proportional to the mass of the object and grows with the square of its speed. ● Student makes comparisons between the *Etiam* and *Chelyabinsk* data that are accurate and use the relationships above. For example, "The mass of *Etiam* is 6.89 x 10^{15} kg, which is a much larger mass than *Chelyabinsk* at 1 x 10^{7} kg. Because the mass of *Etiam* is much larger, this means it will proportionally have much more kinetic energy. This is also shown by its greater speed at 103,450 km/h, compared to *Chelyabinsk's* speed of 60,000-69,000 km/hr. This helps us predict that *Etiam* will have much more kinetic energy to transfer to Earth, causing more damage than *Chelyabinsk."*

8th Grade Science Unit 1: Colossal Collisions

3-Dimensional Individual Project Rubric

Rubric 4: Student draws a model to represent a potential deflection strategy and explains how mass and gravity could affect *Etiam*'s trajectory using this solution.

- Dimensions Assessed: CCC – Systems and System Models, DCI – PS2.B: Types of Interactions

Emerging (1)	Developing (2)	Proficient (3)	Advanced (4)
Student draws an **irrelevant** model to represent a potential deflection strategy that **does not** use the effect of mass on gravitational attraction.	Student draws a **relevant** model to represent a potential deflection strategy but **does not accurately** explain how mass and gravity could affect *Etiam*'s trajectory using this solution.	Student draws a **relevant** model to represent a potential deflection strategy and **accurately, but partially** explains how mass and gravity could affect *Etiam*'s trajectory using this solution.	Student draws a **relevant** model to represent a potential deflection strategy and accurately **and completely** explains how mass and gravity could affect *Etiam*'s trajectory using this solution.
Look Fors: • Student diagrams and/or explains an irrelevant solution that does not use the concepts of mass and gravity. For example, their solution is to catch *Etiam* with a soft surface. This solution is valid, but does not use concepts of mass and gravity.	**Look Fors:** • Student's solution is relevant (prevents or mitigates effects of an asteroid collision) and utilizes the relationship of mass and gravity. For example, using another large object to attract *Etiam* and divert it off its trajectory towards Earth. • Model uses arrows, but no captions to show the interactions and flow of energy and matter within this deflection system. • Student does not explain the diagram at all or does not accurately explain how it works in terms of mass and gravity.	**Look-Fors** • Student's solution is relevant (prevents or mitigates effects of an asteroid collision) and utilizes the relationship of mass and gravity. For example, using another large object to attract *Etiam* and divert it off its trajectory towards Earth. • Model uses arrows or captions to show the interactions and flow of energy and matter within this deflection system. • Student explains the solution in a way that is accurate but lacks detail, using the concepts of mass and gravity. For example, "This solution would use an object with large mass to attract *Etiam* with gravity and change its trajectory."	**Look Fors:** • Student's solution is relevant (prevents or mitigates effects of an asteroid collision) and utilizes the relationship of mass and gravity. For example, using another large object to attract *Etiam* and divert it off its trajectory towards Earth. • Model uses arrows or captions to show the interactions and flow of energy and matter within this deflection system. • Student explains the solution, using the concepts of mass and gravity. For example, "This solution would use another large object to change *Etiam*'s trajectory. This works because the larger the mass of an object, the more gravitational pull it has on other objects. The object would have to be large, like the moon, in order to attract *Etiam* off its course to hit Earth."

8th Grade Science Unit 1: Colossal Collisions
3-Dimensional Individual Project Rubric

Rubric 5: Student develops models of potential design solution(s) to prevent a collision and uses Newton's laws to explain why the solution(s) work.

- Dimensions Assessed: DCI – PS2.A: Forces and Motion, SEP – Developing and Using Models

Emerging (1)	Developing (2)	Proficient (3)	Advanced (4)
Student develops models of **irrelevant** potential solution(s) to prevent a collision that **does not** use Newton's laws.	Student develops models of **relevant** potential design solution(s) to prevent a collision that uses Newton's law(s) **but does not use** Newton's laws to accurately explain why the solution(s) work.	Student develops models of relevant potential design solution(s) to prevent a collision **and uses some of** Newton's laws to accurately explain why the solution(s) work.	Student develops models of relevant potential design solution(s) to prevent a collision and uses **all of** Newton's laws to accurately explain why the solution(s) work.
Look Fors: ● Student diagrams and/or explains irrelevant solution(s) that do not use the concepts of Newton's three laws. For example, their solution is to divert *Etiam* from its trajectory by using the gravitational attraction of another object with a large mass. This solution is valid, but does not use concepts of Newton's laws.	**Look Fors:** ● Student models solution(s) that use some or all of Newton's laws. For example, student diagrams two solutions: 1) Blow up *Etiam* in space, so that smaller pieces will hit Earth. 2) Build a cushion on Earth for *Etiam* to bounce off of in order to prevent damage. ● However, student either offers no explanation or does not explain how they work in terms of Newton's laws.	**Look Fors:** ● Student models solution(s) that use some or all of Newton's laws. For example, student diagrams one solution that uses two of Newton's laws: 1) Blow up *Etiam* in space, so that smaller pieces will hit Earth. ● Student explanations of the model(s) use concepts of some (one or two), but not all of Newton's three laws to explain how the solution(s) work. For example, "This solution uses Newton's first law, since *Etiam* will stay in motion in the same direction until the force of a missile acts on it, changing its speed and direction as it breaks it into pieces. This also uses Newton's second law, which states that the pieces with less mass than the whole asteroid will hit Earth with less force."	**Look Fors:** ● Student models solution(s) that use all of Newton's laws. For example, student diagrams two solutions: 1) Blow up *Etiam* in space, so that smaller pieces will hit Earth. 2) Build a cushion on Earth for *Etiam* to bounce off of in order to prevent damage. ● Student explanations of the model(s) use concepts of each of Newton's three laws to explain how the solution(s) work. For example, "The first solution uses Newton's first law, since *Etiam* will stay in motion in the same direction until the force of a missile acts on it, changing its speed and direction as it breaks it into pieces. This also uses Newton's second law, which states that the pieces with less mass than the whole asteroid will hit Earth with less force. The second solution uses Newton's third law as the cushion creates an equal and opposite reaction that reflects it back into space."

Rubric 6: Student describes the experiment conducted to test potential solutions and uses test data to evaluate how well each met the design criteria.

- Dimensions Assessed: DCI – ETS1.B: Developing Possible Solutions, SEP – Planning and Carrying Out Investigations, SEP – Engaging in Argument From Evidence

Emerging (1)	Developing (2)	Proficient (3)	Advanced (4)
Student describes an **inaccurate or irrelevant** experiment conducted to evaluate potential solutions **and/or does not use** test data to evaluate how well each met the design criteria.	Student **generally** describes the experiment conducted to test potential solutions **and** uses test data to **incompletely** evaluate how well each met the design criteria.	Student **partially** describes the experiment conducted to test potential solutions **and/or** uses test data to **partially** evaluate how well each met the design criteria.	Student **completely** describes the experiment conducted to test potential solutions **and** uses test data to **completely** evaluate how well each met the design criteria.
Look Fors: • Student's experiment is not relevant to the project. For example, "We tested if a heavier ball would cause more pennies to fall over." • And/or student does not use the test data or provide any reasoning for their evaluation of each solution. For example, "Solution 1 worked the best."	**Look Fors:** • Student describes the experiment they did to test all solutions, but description is very general and missing most components listed in the right-hand column. Experiments will vary. For example, "We did an experiment where we rolled a ball at the different solutions to see which ones prevented the most pennies from falling over." • Student also only evaluates one solution, and does so without detail. For example, "We learned that a barrier is the best option because it prevents a collision."	**Look Fors:** • Student describes the experiment they did to test all solutions, identifying some, but not all components listed in the right-hand column. Experiments will vary. • And/or student evaluates some, but not all of the solutions in terms of criteria and constraints. For example, "Solution 2, a barrier, worked best because it succeeded in deflecting "*Etiam"* to not hit "Earth", which meets the criteria of the problem." Student writes a description like this for some of the other solutions.	**Look Fors:** • Student describes the experiment they did to test all solutions, identifying independent variable, dependent variable, controls, materials, procedure, and data collection. Experiments will vary. • Student evaluates all of the solutions in terms of criteria and constraints. For example, "Solution 1, in which we placed diagonal Popsicle sticks right in front of Earth, succeeded in deflecting "*Etiam"* sideways away from "Earth", but then the Popsicle sticks hit "Earth", so this didn't fully meet the criteria." Student writes a description like this for all other solutions.

8th Grade Science Unit 1: Colossal Collisions

3-Dimensional Individual Project Rubric

Rubric 7: Student draws and describes a final design solution and explains how it combines best characteristics of different designs.

- Dimensions Assessed: DCI – ETS1.C: Optimizing the Design Solution, SEP – Designing Solutions

Emerging (1)	Developing (2)	Proficient (3)	Advanced (4)
Student draws and describes a final design solution that **does not combine** best characteristics of different designs.	Student draws and describes a **relevant** final design solution but **does not explain** how it combines best characteristics of different designs.	Student draws and describes a **relevant** final design solution and **partially** explains how it combines best characteristics of different designs.	Student draws and describes a **relevant** final design solution and **completely** explains how it combines best characteristics of different designs.
Look Fors: • Student drawing and description show a design solution that is either irrelevant to the forces and motion concepts of this unit OR does not combine best characteristics of different designs.	**Look Fors:** • Student drawing and description show a design solution that is relevant to the forces and motion concepts of this unit and combines best characteristics of different designs. See example to right. • Student does not explain which characteristics were combined and why.	**Look Fors:** • Student drawing and description show a design solution that is relevant to the forces and motion concepts of this unit and combines best characteristics of different designs. See example to right. • Student explains which best characteristics they incorporated from different designs, but does not explicitly explain why. For example, "We created a barrier that incorporated the soft foam material from Design Solution 1 and the farther placement from Earth from Design Solution 2."	**Look Fors:** • Student drawing and description show a design solution that is relevant to the forces and motion concepts of this unit and combines best characteristics of different designs. For example, a barrier made of soft material and placed farther away from Earth. • Student completely explains which best characteristics they incorporated from different designs and why. For example, "In one of the designs, we used popsicle sticks, but the ball bounced back a lot. In another design, we used a foam barrier, but it was too close to the pennies, so the ball pushed the barrier into the pennies. These results made us decide to create a soft barrier, like the foam, but place the barrier farther from Earth, like the popsicle sticks."

8th Grade Science Unit 1: Colossal Collisions
Project Organizer

Unit Essential Question: *What are the effects of an asteroid collision and how can we prevent a future one?*

You will be designing a solution to prevent the impending collision of the asteroid *Etiam* with Earth. After each task, you will return to the table below to organize what you learn as you go through the unit. By the end of the four tasks, you will have all this information to use for your culminating project. For each activity, be sure to include answers to **ALL** the questions provided.

<table>
<tr><td rowspan="2">Lift-Off Task: Asteroid Collisions</td><td>In order to develop a solution to an impending collision with the asteroid Etiam, we need to learn everything we can about the impacts of an asteroid collision.
❑ Summarize what you already know about collisions, including:
○ Possible negative consequences.
○ The types of methods humans use to prevent every-day collisions.</td></tr>
<tr><td></td></tr>
<tr><td rowspan="2">Task 1: An Ancient Collision</td><td>Today we learned that there has already been an asteroid collision in the past that had huge consequences. Use this ancient collision to justify your design solution:
❑ What evidence is there that this has happened before?
❑ What were the effects last time?
❑ How will you use the evidence to convince the public that it is important to protect Earth from another asteroid collision?</td></tr>
<tr><td></td></tr>
</table>

8th Grade Science Unit 1: Colossal Collisions

Project Organizer

Task 2: Contact Forces	In this task, you explored and studied how different contact forces and factors like mass help predict the motion of objects. Now, let's use these ideas to start deciding how to deflect *Etiam* from its path towards Earth. ❒ How will *Etiam's* large mass affect Earth? Use experimental evidence from the task as well as scientific ideas of mass, kinetic energy, and speed to back up your response. ❒ How can Newton's three laws help us predict and explain what will happen when *Etiam* hits Earth? ❒ Record ideas you have on deflecting *Etiam*, using the following questions to help you: ○ In the experiments, which solutions worked best? ○ Based on the data, can you combine characteristics from the best solutions to create an even better one? ○ How does each solution use contact forces and your understanding of mass and motion?

8th Grade Science Unit 1: Colossal Collisions

Project Organizer

Task 3: Gravity – A Non-Contact Force	In this task, you learned about another, less tangible force that also affects the motion of *Etiam*. Look back at the trajectory of *Etiam* from your Culminating Project handout and brainstorm where this force may help you prevent *Etiam's* collision with Earth. ❒ Draw a diagram showing how gravity is currently influencing *Etiam.* ❒ What other objects in our solar system might influence *Etiam's* movements as it travels through space? Why? ❒ Illustrate moments in *Etiam's* trajectory where the asteroid might be impacted by other gravitational forces in a way that changes its trajectory. ○ Explain how this works.

8th Grade Science Unit 1: Colossal Collisions
Lift-Off Task: Asteroid Collisions

Unit Essential Question: *What are the effects of an asteroid collision and how can we prevent a future one?*

Introduction

It is largely believed that about 65 million years ago, a large asteroid collided with Earth, causing a huge explosion and a cascade of worldwide effects—the most well-known effect being the extinction of dinosaurs from our planet. In this Lift-Off Task, students are introduced to the phenomenon of this historical asteroid collision and asked to generate a list of questions they would ask in order to learn more. As they explore these questions throughout the unit, students will begin to conceptualize the potential impacts of an asteroid collision and start to envision what kinds of solutions they could use to prevent another large-scale collision with Earth, which is their culminating project for this unit.

Alignment Table

Because the Lift-Off Tasks focus on student-generated questions, we do not identify specific Disciplinary Core Ideas or Science and Engineering Practices in this table.

Crosscutting Concepts (*depending upon student-generated questions)
• Patterns
  ○ Graphs, charts, and images can be used to identify patterns in data.
• Scale, Proportion, and Quantity
  ○ Proportional relationships (e.g. speed as the ratio of distance traveled to time taken) among different types of quantities provide information about the magnitude of properties and processes.
• Systems and System Models
  ○ Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy and matter flows within systems.
• Stability and Change
  ○ Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and forces at different scales.

Equity and Groupwork • Share and listen to broad and diverse student contributions. • Make connections between each other's ideas. • Work together to co-construct a concept map.
Language • Use connector words to link ideas. • Generate and write questions about the phenomenon. • Organize key questions in a concept map.

Learning Goals

This learning task introduces students to the concept of a species changing over time and begins generating questions that will guide them through this unit. More specifically, the purpose is to:

- Individually generate a list of questions about an asteroid collision.
- Make connections between related questions.
- Generate possible answers to questions, based on prior knowledge.

8th Grade Science Unit 1: Colossal Collisions
Lift-Off Task: Asteroid Collisions

- Apply prior knowledge of collisions to identify possible negative impacts caused by an asteroid collision with Earth.

Content Background for Teachers

All around us, objects are moving and often colliding. Since students experience motion and collision all the time, this is not a new concept to them. However, an asteroid collision with Earth may be new to them. While we do not expect students to know this phenomenon specifically, most will come to this unit with some prior knowledge around collisions (like car or bicycle crashes) and may know some facts about asteroids.

In this task, we are building off of students' prior knowledge of asteroids and collisions, asking them to generate questions they would need to ask to make sense of the phenomenon for this unit—a possible historical asteroid collision. These might be questions related to asteroids in general, collision of objects, impacts on Earth, and much more.

As students draw off their prior knowledge of collisions, they will likely begin to think about motion, at least implicitly. This is one of the main focuses of this unit. When studying motion, it all revolves around forces. Forces need to act upon an object to begin its motion, end its motion, or change its motion. In later tasks, students will learn about both contact forces and non-contact forces (like gravity), which affect movement. Students will also learn about other factors related to motion, such as the mass of objects, speed, and kinetic energy. All of these concepts not only apply to motion, but collisions as well. Thus, these scientific ideas will not only help students understand the movement of asteroid *Etiam* toward Earth (the culminating project), but will also provide ways to prevent the collision. Additional background information on these specific topics, as well as the ancient asteroid collision will be provided in later tasks.

In this task, students create a concept map, which is a graphical tool that helps to organize and represent knowledge and questions, and is a successful academic language instruction tool. As students learn more about asteroid collisions and associated concepts, they will add more questions and ideas to this concept map. If your students have not had previous experience making concept maps, please see the instructions in Part B below for strategies on teaching this skill.

Academic Vocabulary

- Asteroid
- Collision (Collide)
- Impact

*Additional academic vocabulary will vary by class

Time Needed (Based on 45-Minute Periods)

2 Days

- Introduction, Part A and Part B: 1 period

8th Grade Science Unit 1: Colossal Collisions
Lift-Off Task: Asteroid Collisions

- Class Concept Map, Project Overview, and Project Organizer: 1 period

Materials

- Unit 1, Lift-Off Task Student Version

Part B

- Poster paper and markers
- Post-Its (Optional)

Part C

- Class Poster Paper and markers
- *See Instructions below for other optional materials to use for the class concept map

Connecting to the Culminating Project

- Culminating Project Handout
- Project Organizer Handout

Instructions

1. Introduce students to the unit by reading or projecting the Unit Essential Question aloud.

2. Read the short paragraph on page 1 of the student guide aloud, which introduces the phenomenon for the unit: an asteroid collision with Earth 65 million years ago.

Part A

1. In this Lift-Off task, students will be generating questions to help them make sense of the phenomenon.

2. Have students complete this section individually in their student guide.
    - For students who need more support, encourage them to use the picture in the student guide to generate questions.
    - Here is a list of some potential questions students might generate: "What is an asteroid? Do asteroids really collide with Earth? How often do they collide with Earth? What are the effects of an asteroid collision? What happened to the Earth when the asteroid hit? How do we know that asteroid collision even happened? What can we do to protect ourselves in the future? Why don't more people know about this problem?"

Part B:

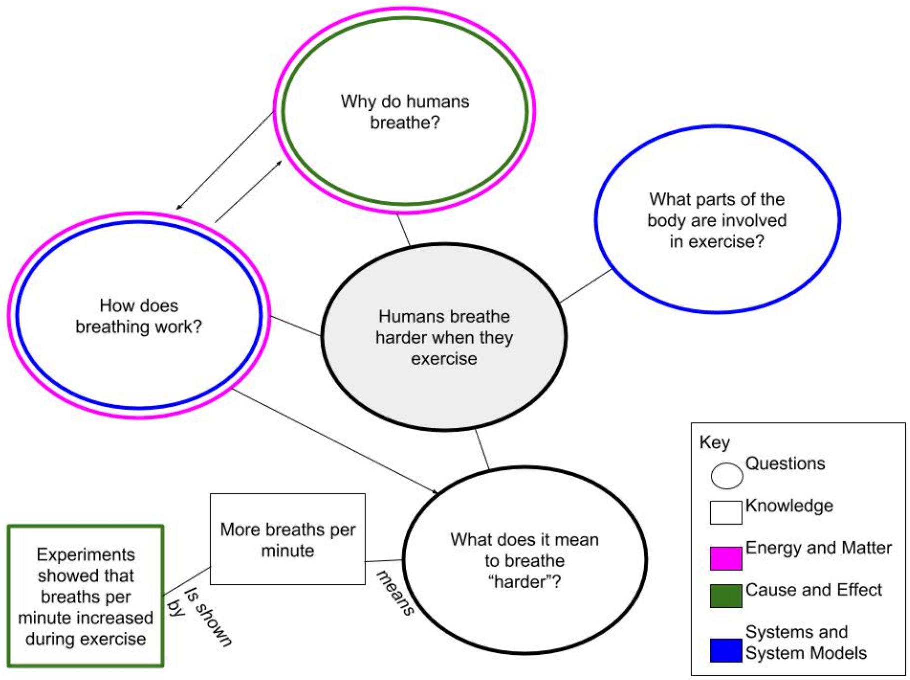
1. In this part of the task, students create a concept map as a group.
    - Remind students to refer to the directions on their student guide to help them make their concept map. First, students should compare each member's list of questions and record/connect key questions on a piece of poster paper. They will then draft possible answers to the questions, using prior knowledge.
    - Remind students that there are no right or wrong questions or predictions, so students feel encouraged to contribute any and all questions and ideas they think of.

- Because this is a collaborative task, it is recommended that you remind students of group work norms and assign group roles, such as Resource Manager, Facilitator, Recorder, and Harmonizer (See "How to Use this Curriculum" for more details).

2. Students will post their posters on a wall and then walk around and look at each group's ideas. One suggestion for gallery walks is for students to interact with the posters in some way. For example, students are required to initial or leave post-its on three questions that they are also excited about on other posters.

How to Concept Map

For students who have not had a lot of experience making concept maps, we have detailed a strategy below for introducing concept mapping using more familiar content. An example is also provided, but this will vary depending on what your students come up with as you make your own model.



1. Write the phenomenon in the middle of the poster, in this case "Humans breathe harder when they exercise."
2. Ask students to share questions they might ask to make sense of this phenomenon and make a list of these questions on the board.
3. Model the process of reviewing the list and finding similarities amongst the questions.
   - Place these key questions on the concept map poster, modeling how to put similar questions near each other on the poster. Circle these to signify that these are questions, not content knowledge.
4. Ask students to look at the key questions and see if any of the questions are connected: Would answering one question lead to one of the other questions? Model making these connections by drawing arrows between the circles.
5. In this Lift-Off task, students will only be drafting possible answers to the questions, not actually gathering and recording learned concepts. However, throughout the unit, they will be adding content

they have learned. Model this by recording a student's prior knowledge to one of the questions, using boxes to signify that these are pieces of content knowledge rather than questions.
   - Use connector words to identify the relationships between the content boxes (See image above for an example).

6. Optional: To emphasize crosscutting concepts using a concept map, make a key of different colors for the crosscutting concepts emphasized in this unit. Identify questions that clearly show evidence of the different crosscutting concepts and circle them with the corresponding colors. Explain to students how you made that choice by pointing out the language that hints at that crosscutting concept. *Note: not all boxes and circles will necessarily have a crosscutting concept.

Part C

1. Construct a whole-class concept map that begins to help students make sense of the phenomenon of asteroid collisions.
   - Start with the phenomenon in the middle.
   - Then ask students to share out the questions that were most common across all the posters in the classroom. As you record questions on the poster, organize them based on connections you see. Draw circles around each question (as you add to the concept map throughout the unit, you'll also be adding concepts learned, which can be written in boxes to distinguish them from the questions).
   - Ask students to identify any connections they see between the questions and record these as lines between the questions.
     - Recommended: Give pairs of students think time to come up with 1-2 connections to add to the class concept map and call on pairs using equity sticks. This encourages more equitable participation in a class-wide activity.
   - The purpose of this concept map is to facilitate generation of student questions, promote language development, and support understanding of the science content throughout the unit. Allowing students to ask their own questions and use their own words to make meaning of the concepts will not only help them make deep connections about science content, but will also help their oral and written language development.
   - This whole class concept map will be revisited at the end of each subunit, asking students questions like: Are there any new questions you have about the phenomenon? Are there any connections you want to add or change? What is your reason for that addition/revision? Are there more connections we can make between the questions/ideas already on the map? Do you want to add any new ideas/concepts to the map?

2. Because this concept map will be added to and revised throughout the unit, here are some practical options for implementation.
   - If you have access to white board paper, we encourage you to use these for class posters since it will allow you and your students to make revisions throughout the unit.
   - Another option is to use smaller pieces of paper for each class and project using a document camera; this will save space as opposed to doing large class posters.

- We highly recommend students keep their own version of this concept map in their notebooks, adding questions and concepts as they go through the unit.

3. Once the draft concept map is complete, introduce students to the crosscutting concepts for this unit. We recommend posting posters of each crosscutting concept in your classroom (See beginning of teacher guide for templates).
    - The crosscutting concepts for this unit are: Patterns; Scale, Proportion, and Quantity; Systems and System Models; and Stability and Change. Assign a color for each crosscutting concept that can be used throughout the unit.
    - Have students analyze the class concept map for as many examples of the crosscutting concepts as they can find. Depending on the questions they have, they may be able to find an example of each of the crosscutting concepts or perhaps just some.
    - We recommend modeling this process by picking a question, identifying the crosscutting concept, and tracing the circle in the corresponding color. Explain the key words that helped you identify the crosscutting concept in this question. Some identifying words that students might look for are:
        - **Patterns**: These could be phrases such as, “is the same as”, “has in common with”, “is similar to”, “shares” etc.
        - **Scale, Proportion, and Quantity**: These could be phrases such as, “is proportional to”, “compared to”, “has a ratio of”, “is bigger/smaller than”, “is longer/shorter than”, etc.
        - **Systems and Systems Models**: These could be phrases such as, “is a part of,” “is related to,” “consists of,” “interacts with,” “works together with,” etc.
        - **Stability and Change**: These could be phrases such as, “remains the same”, “is changed by”, “is disrupted by”, “changes”, “disrupts”, etc.

Connecting to the Culminating Project

1. Hand out the Culminating Project Task Card and read the Challenge and Group Project Criteria for Success aloud as a class.
    - Take questions for clarification.

2. Give a brief overview of the Background data on the asteroid, *Etiam*, emphasizing that students will need to return to this data and review it more thoroughly as they get closer to the project.

3. Pass out their Project Organizer and explain that they will complete a section of this after each task in class. Students should independently complete the Lift-Off Task section of the Project Organizer in class. Revisions can be done for homework, depending upon student’s needs and/or class scheduling.
    - Students have been tasked with designing a solution to prevent the impending collision of the asteroid *Etiam* with Earth. The student prompt is as follows: In order to develop a solution to an impending collision with asteroid *Etiam*, we need to learn everything we can about the impacts of an asteroid collision. Summarize what you already know about collisions, including:
        - Possible negative consequences.
        - The types of methods humans use to prevent every-day collisions.

Reflection

1. At the end of the task, ask students to reflect on what they have learned over the course of this task by answering the following three questions in their student guide:
    - At the beginning of this task, you made a list of all the questions you have about the historical asteroid collision from 65 million years ago. Look back at your list: think about the questions your peers asked that you did not initially write down. How are their questions different from the ones you originally asked?
    - In this unit, we will be focusing on four crosscutting concepts: **Patterns:** Graphs, charts, and images can be used to identify patterns in data; **Scale, Proportion, and Quantity**: there are proportional relationships between different types of quantities; **Systems and System Models**: Models can be used to represent systems and their interactions; **Stability and Change:** We can examine changes over time at different scales to explain stability and change. Looking at your class concept map, give one example of how a crosscutting concept came up in today's task.
    - Now that you understand what project you'll be working on over the course of this unit, what else do you need to know? What additional questions do you have?

2. There are no right answers, but encourage students to look back at their initial lists and their class concept map. They should not change their initial responses, but rather use this reflection space to add to their questions and ideas based on what they have learned through this task. By generating more of their own questions, students continue to engage in sense-making of the phenomenon and the gathering of knowledge and skills for their final project.

8th Grade Science Unit 1: Colossal Collisions

Task 1: An Ancient Collision

Unit Essential Question: *What are the effects of an asteroid collision and how can we prevent a future one?*

Introduction

At the end of the Lift-Off Task, students were introduced to the motivation behind this unit—an impending asteroid collision with Earth. In this task, they will learn more about how this phenomenon is not new, and that there is great evidence suggesting that a collision of this magnitude has indeed happened before. In stations, students will analyze different pieces of evidence that document the existence, diversity, extinction, and change of life forms on Earth over time. By observing similar patterns of change in the data, they will be able to confirm that a major asteroid collision occurred 65 million years ago and it had drastic effects. By gathering this evidence, students will be able to explain to the public in their project why it is so important that they do everything they can to prevent something like this happening again.

Alignment Table

Performance Expectations	Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
MS-LS4-1. Analyze and interpret data for patterns in the fossil record that document the existence, diversity, extinction, and change of life forms throughout the history of life on Earth under the assumption that natural laws operate today as in the past. [Clarification Statement: Emphasis is on finding patterns of changes in the level of complexity of anatomical structures in organisms and the chronological order of fossil appearance in the rock layers.] [Assessment Boundary: Assessment does not include the names of individual species or geological eras in the fossil record.]	**Analyzing and Interpreting Data** • Analyze and interpret data to determine similarities and differences in findings.	**LS4.A: Evidence of Common Ancestry and Diversity** • The collection of fossils and their placement in chronological order (e.g., through the location of the sedimentary layers in which they are found or through radioactive dating) is known as the fossil record. It documents the existence, diversity, extinction, and change of many life forms throughout the history of life on Earth.	**Patterns** • Graphs, charts, and images can be used to identify patterns in data. • Patterns can be used to identify cause and effect relationships. (*Supplementary)*
Supplementary Science and Engineering Practices • Constructing Explanations o Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students' own experiments) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.			

8th Grade Science Unit 1: Colossal Collisions

Task 1: An Ancient Collision

Equity and Groupwork • Discuss how data provides evidence of a great asteroid collision. • Share CER reports and learn from others.
Language • Use analytical terminology to discuss graphs. • Write a CER report. • Use the Stronger Clearer protocol to strengthen the language of an explanation.

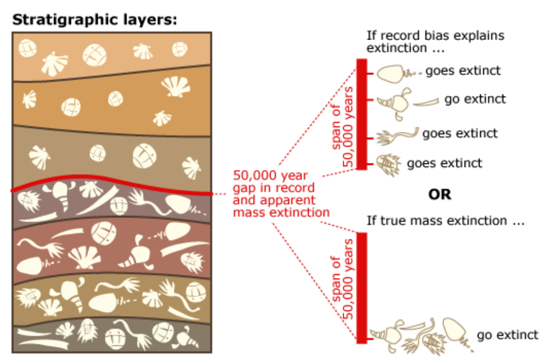
Learning Goals

This learning task asks students to analyze the fossil record for evidence that a mass extinction occurred in the past due to an asteroid collision. More specifically, the purpose is to:

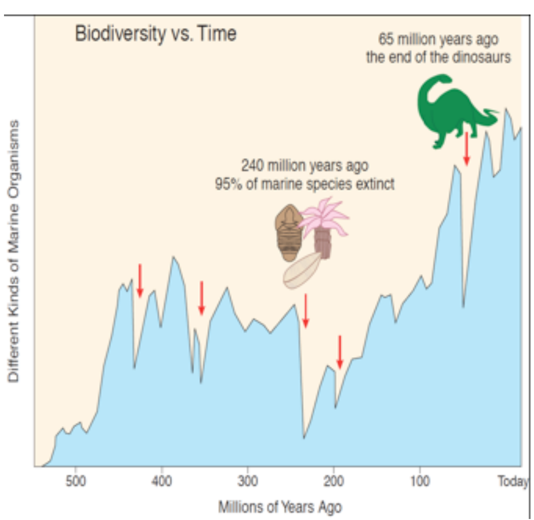
- Engage prior knowledge of asteroid collisions and dating soil layers.
- Analyze and interpret data for patterns in fossil data that document mass extinction of species.
- Explain whether a large asteroid has hit Earth before and what the consequences were.
- Use the "Stronger and Clearer" method to revise the language and ideas in their CER paragraph.
- Apply knowledge of a past asteroid collision to justify protecting Earth against another collision.

Content Background for Teachers

According to abundant evidence, an asteroid approximately 6 miles across collided with Earth 65 million years ago. The impact created a huge explosion that killed many organisms and thrust debris into the atmosphere, dramatically altering the climate. This led to the extinction of millions of species, most notably the dinosaurs.



In the stations, students will be able to look at re-creations of soil layers and the associated fossils to do their own fossil analysis, as well as look at graphs and written data created from scientific fossil analysis.



Across all stations, they will find evidence that there are striking "breaks" that occur in the fossil sequence—these are the mass extinctions that have occurred several times throughout the history of life on Earth. A mass extinction can be defined as a widespread and rapid decrease in the biodiversity of life on Earth. As is the case today, habitat loss and climate change were major contributors to mass extinction.

Students will also find that in the case of the mass extinction 65 million years ago, scientists have gathered enough evidence to determine what caused this mass extinction—a large asteroid impact. The following are a few lines of evidence that help to prove this: Iridium, a common component of asteroids, can be found in the 65 million year old soil layer at many points around the world. The same soil layer contains grains of quartz (a type of rock) that were deformed by high shock pressures, as would occur in a giant explosion. The same soil layer also contains enough soot to correspond to burning down all of the forests of the world. This suggests that massive fires were touched off at the time of impact. For more information on the fossil and soil data, please see the station cards associated with this task.

This mass extinction event serves as the background and the motivation for students' culminating project for this unit. In this task, students examine soil and fossil evidence that not only proves that an asteroid collided with Earth 65 million years ago, but also that it had dramatic consequences. By doing so, students will be able to justify the need behind them finding a solution to thwart the impending collision described in their culminating project.

Academic Vocabulary
- Extinction (Mass)
- Layers
- Fossil
- Biodiversity
- Pattern

Time Needed (Based on 45-Minute Periods)
5 Days
- Engage and Explore: 1 period
- Explore (continued): 1 period
- Explain: 1 period
- Elaborate: 1 period
- Evaluate and Reflection: 1 period

Materials
- Unit 1, Task 1 Student Version

Explore
- Resource Cards 1 - 5: two - three per station

Evaluate
- Project Organizer Handout

Instructions

Engage
1. Introduce Task 1: In the Lift-Off Task, we heard about a theory of an asteroid collision with Earth 65 million years ago. Think about what you were still wondering about at the end of the last task (look back if you need to). What questions do you still have?
    - Before you pass out their student guide, give students time to reflect individually or with a partner about the questions they recorded at the end of the last task. Share a few of these out as a class, using facilitating questions to guide students toward questions that relate to this task.

2. Transition to Task 1: In the Culminating Project Challenge, we found out that an asteroid, called *Etiam*, is headed towards Earth, so we need to learn everything we can to help prevent this. There is a theory that a large asteroid hit Earth 65 million years ago. What might be the consequences of an asteroid colliding with Earth?
    - Now pass out their Task 1 student guide.

3. Students pool the prior knowledge of their group members to see if they can guess what asteroid collision this refers to—the one that killed the dinosaurs.
    - Share out a few guesses. Most likely, there will be at least one group in your class who can identify this asteroid collision. If no groups come up with this guess, identify it as the one that killed the dinosaurs.

4. Introduce students to the kind of data they will be analyzing in this task: the fossil record.
    - In this portion of the Engage, pairs of students will use logic to think about what layers are the oldest and the youngest.
        i. If students are stuck, present scenarios that help them think about layering (for example, would the most recent leaves dropped from a tree be on the top layer or buried underneath the soil?) Students may also use the organisms in the layers as clues (for example, there is a human skull at the top layer).
    - Students will then choose one species from the drawing and hypothesize why it has changed from generation to generation. This will build off prior knowledge of adaptation processes from earlier grades. It also encourages students to begin exploring the crosscutting concept of **Patterns**, as they use the image to identify patterns in this particular source of data—the fossil record.
    - We recommend that you also ask students to share out a few responses, so all students begin the *Explore* with similar understandings. The use of equity sticks is encouraged for more equitable participation in class-wide discussions (See "How To Use This Curriculum" for more details).

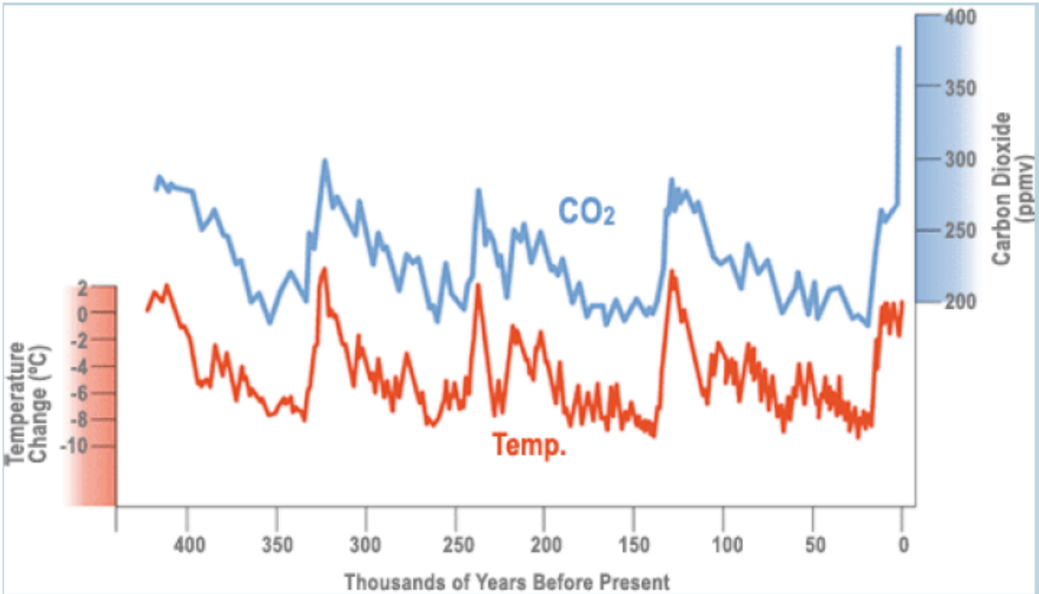
Explore

1. The introduction on their student guides sets the context in which they are collecting data and the reason why it is so important they collect this data, so we recommend reading this aloud.
    - In this section of the task, each group of students will visit stations to look at evidence for one type of event in the fossil record—an asteroid collision and the corresponding mass extinction. This gives students practice at **Analyzing and Interpreting Data**, as they look for similarities and differences amongst the data that might give them clues about an asteroid collision 65 million years ago.

2. We recommend first modeling general graph analysis skills.
    - Optional: project the graph below for students to analyze. Emphasize that while this graph has nothing to do with the task, it will help them practice how to analyze graphs like the ones they will see today.

8th Grade Science Unit 1: Colossal Collisions

Task 1: An Ancient Collision



DATA: Petit, J.R., et al., 2001; NOAA/NGDC Paleoclimatology Program, Boulder CO, USA.

- Have students first look at the axes and what is being graphed. With a partner, have students describe what the graph is about in their own words (this isn't the analysis… but it helps them get acquainted with the graph. Note that 0 is present (maybe write this on the board).
- Provide some questions and criteria for analysis.
  - What is the graph measuring, according to the axes?
  - Describe patterns (repetitions) using axes labels.
  - Describe exceptions to patterns… are there parts of the graph that are different than the pattern?
  - If there is no pattern, say there is no pattern.
- Provide some sentence starters
  - If there are patterns: "As _________ increases/decreases, ___________ increases/decreases…" (Hint: Look for patterns of peaks).
  - If there are exceptions to patterns: "However, from (some part of the graph)… we can see a difference in the pattern." (Hint: Look for an area that doesn't look like the pattern of peaks).
- Graph conclusions: Both temperature change and carbon dioxide decreased and increased from 450,000 years ago to the present. From about 440,000 years ago to 330,000 years ago, temperature change and carbon dioxide decreased. There were some small increases and decreases in the overall pattern during this time. Then there was a jump in both carbon dioxide and temperature. There were three more cycles like this. The carbon dioxide and temperature changes paralleled each other, but just before the present, the carbon dioxide increased to more than it was at any other point on the graph and the temperature didn't increase so dramatically.
- Lastly, write the following graph analysis facilitating questions on the board that students may use as they analyze the graphs in the stations:
  - What does each axis of the graph say? What are the units?

- What does the graph measure?
- What patterns do you notice on the graph?
- Are there any exceptions to the pattern?

3. We also recommend modeling the process of analyzing and interpreting the data on the station cards with Station Card 1.
    - Project Station Card 1 and look at the picture together.
    - Model how to fill out the data analysis chart, including discussing and recording responses to the discussion questions.
    - Optional: provide students with fossil "samples" to look at as they examine the station card (https://www.carolina.com/earth-science-fossils-geologic-time/mesozoic-fossil-collection/GEO5322.pr?intid=jl_pdp&jl_ctx=on_site).

4. Assign roles to each group. You may use whatever roles you prefer. We recommend the use of the Materials Manager, Facilitator, Harmonizer, and Recorder.
    - Ask Facilitator to read the directions and to make sure everyone understands the task.
    - Ask the Materials Manager to handle any resources needed to complete the task.
    - Ask the Harmonizer to make sure that everyone contributes their ideas and that everyone's voice is heard.
    - Ask the Recorder to make sure the group is recording their data analysis in their student guides.

5. Set up 4+ stations around the room for Station Cards 2 - 5 (you may need to have duplicate stations depending on the number of student groups you have). At each station, lay out 2-3 copies of one station card.
    - Students will circulate between the stations to gather evidence. It is recommended that you set a specific time for each station (approximately 7 minutes) so students really spend time doing deep analysis of the data.
    - Walk around and listen to the kind of evidence students are discussing.
        - Try not to provide any explicit analysis, but you may point out parts of the data to focus on if students are struggling.
        - The discussion questions provided on the station cards are meant to provide facilitation and scaffolding for the data analysis.
        - As students analyze the data, you should begin to notice students finding **Patterns** both within one station as well as between stations. This continues students' engagement with the crosscutting concept highlighted in this task, as students use graphs, charts, and images to identify patterns in the data.
    - Students should fill out the data collection table in their student guide in order to record and organize their findings.

6. Optional: Conduct a whole-class debrief that brings out the **patterns** students saw in the data.
    - Students should notice related patterns of high extinction rates, decreased biodiversity, change in soil composition, and changes in the complexity of organisms, which represent times of mass extinctions.

- Again, the use of equity sticks is encouraged for more equitable participation in class-wide discussions like these (See "How To Use This Curriculum" for more details).

Sample Student Data Analysis Chart

	Type of Data (Graph, image, description, etc)	Observations: What do you see?	Responses to the Discussion Questions
Resource Card 1	Image	I see many different layers of soil. The layers below the red line have lots of different organisms, while above the red line there are less.	1. The layers below the red line have more organisms and there is a greater variety in type. The layers above the red line show the opposite. 2. A mass extinction
Resource Card 2	Description	There is not only evidence in fossil data but also soil data for an asteroid collision. The fossil record shows "breaks" in the sequence. The soil shows a layer 65 million years ago that contains iridium, quartz, and soot—all evidence for an asteroid collision.	1. There are "breaks" in the fossil record. 2. Iridium, commonly found in asteroids, is in the layer from 65 million years ago. There is also deformed quartz from an explosion and soot from the subsequent burning. 3. The soil evidence shows that an asteroid collision was the cause of the mass extinction shown in the fossil record (effect).
Resource Card 3	Graph	The graph shows many large dips in biodiversity over time, shown with red arrows. The dip 65 million years ago involves the end of the dinosaurs.	1. It does not. Sometimes it dips a lot or a little and, sometimes it increases. 2. The red arrows represent times where biodiversity of marine organisms has decreased a lot. a. The cause could be something like an asteroid collision or a dramatic change in climate. 3. There is also a large dip in biodiversity, specifically the end of the dinosaurs.
Resource Card 4	Graph	There are 5 spikes in the extinction rate over the history of	1. The dips in biodiversity are at the same points as the spikes

		life on Earth. The rest consists of much smaller spikes in extinction rate.	in extinction rate. a. Less biodiversity means the death of many species, which thus means a higher extinction rate. 2. Mass extinction is when lots of species go extinct suddenly, but background extinction seems to be when fewer species go extinct. a. If it is big enough, most likely a mass extinction because it has a huge impact and can change the climate.
Resource Card 5	Image	It looks like there were once many different kinds of leaves, but after the K-T line, the leaves are much more similar.	1. The layer below the dotted line has much more variety in the types of organisms. 2. Most of them became extinct because of some drastic change in environment. a. It could have been an asteroid collision. 3. Some of the fossils stay the same one layer to the next, while others seem to show gradual changes, for example in size and shape.

Explain

1. This section of the task asks students to use all of the evidence they have gathered and come to a conclusion: Did a large asteroid hit Earth before? If so, what were the consequences? This emphasizes the crosscutting concept of **Patterns** as students use patterns in the data to identify a cause-and-effect relationship between the asteroid collision and the various effects.

2. Students write a CER paragraph to draw these conclusions.
   - They should include data analysis chart from the last section of the task as evidence. Here, students are **Constructing Explanations** using evidence and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.

- Optional scaffold: Write a claim together as a class and brainstorm an example of a piece of evidence from the stations that could be used to support the claim.

Optional Sentence Stems to Provide:

Claim	Based on the evidence, we can conclude that a large asteroid (has/has not) hit Earth before. The evidence suggests that the asteroid collision resulted in…
Evidence	There are several pieces of evidence for an asteroid collision 65 million years ago. When observing soil layers from 65 million years ago, you can see… The soil layers also show… When looking at the fossil record from 65 million years ago, we can also see… This means that… This can also be shown in a graph of…
Reasoning	All of these pieces of evidence show that… The asteroid collision not only did ___, it led to… This is what caused… This is why we see ____ in the soil record at the same time as ____ in the fossil record. If an asteroid collision happened today, …

Sample CER Report

Claim	Based on the evidence, we can conclude that a large asteroid has hit Earth before. The evidence suggests that the asteroid collision resulted in a mass extinction of species.
Evidence	There are several pieces of evidence for an asteroid collision 65 million years ago. When observing soil layers from 65 million years ago, you can see the presence of iridium, a common component of asteroids. The soil layers also show a presence of quartz deformed by a high-pressure shock and soot from the subsequent burning of forests around the world. When looking at the fossil record from 65 million years ago, we can also see a large decrease in biodiversity—in other words, that many species of organisms went extinct. This can also be shown in a graph of a high rate of extinction at this time.
Reasoning	All of these pieces of evidence show that there was an asteroid collision 65 million years. It not only distributed pieces of asteroid, but also caused massive fires and climate change. This in turn was what caused the mass extinction that followed, which is why we also see evidence of a mass extinction at the same time in the fossil record. If an asteroid collision happened today, we would likely see similar impacts.

3. Optional peer review: Have table partners switch CER paragraphs and make suggestions for revisions.

Elaborate

1. This part of the task gives students practice at checking for understanding amongst their peers and making revisions for both content and language.
    - This academic language tool is known as the "Stronger and Clearer" method, and will help students strengthen and clarify language and ideas in their CER report. As they talk to peers, they can build from their ideas and borrow language from their partners.

2. Introduce the purpose of the task, as outlined in their student guide.
    - Begin by having students look back at their own CER paragraph and recording any ideas and language they really liked from their own CER (chart provided in their student guide). This will not only help them start with a positive reflection of their own work, but will also give them practice with the process they will use in this activity.

3. This activity can be set up in different ways, but we recommend having students form two concentric circles, so that partners are facing each other.
    - Review the instructions aloud with students.
    - As students go through the "Stronger and Clearer" process, call out time reminders to students, so they stay on task (adjust times as needed to fit your students' needs).
        i. 1 minute for each person to share, 1 minute to discuss each partner's CER, 1 minute to record. These time breakdowns are written in the student guide as well.
    - After 5 minutes, ask students in the inner circle to rotate one space to the right, so they have a new partner. Repeat the process again.
    - Optional: Repeat this more times with more partners, so students have additional models to learn from.

4. Once finished with partner sharing, have students return to their seats to write a new version of their CER, incorporating the new ideas and language they have gathered.
    - It is important to remind students that while learning from others is encouraged, direct copying is not acceptable.
    - This is a great option for a formative assessment. Collect student work to identify trends in students' ability to use multiple patterns as evidence for an explanation. See "How to Use This Curriculum" for strategies on utilizing formative assessment data to provide feedback to students and inform classroom instruction.

5. Return to the whole-class concept map from the Lift-Off Task.
    - In small groups, have students brainstorm new concepts and new connections that they have learned in this task, as well as any new questions that have come up for them. Then have groups share these aloud in a class-wide discussion and add to the class concept map. The use of equity sticks is encouraged for more equitable participation in class-wide discussions (See "How To Use This Curriculum" for more details).
        - Some facilitating questions to ask students are: What new ideas/concepts do you want to add to the map? What connections do you want to add or change? What is your reason for that addition/revision? What connections can we make between the questions/ideas already on the map? What new questions do you have about the phenomenon?
        - Draw circles around each question and boxes around each concept.
        - Write connector words to describe connections between the concept boxes.
        - For this task, students may begin to connect some of their previous question circles to concept boxes about the following: patterns in the fossil record, changes in biodiversity over time, and mass extinctions.
    - Have students analyze the additions to the class concept map for as many examples of this task's crosscutting concept as they can find. Once a student has identified the crosscutting concept, you

can trace the circle in the corresponding color (decided on in the Lift-Off task). We recommend asking students to share key words that helped them identify the crosscutting concept for that concept or question. Some identifying words students might look for are:
    - **Patterns**: These could be phrases such as, "has in common with" "shares," "is also shown in," "is the same as," "looks the same as," etc.
- Once again, the purpose of this concept map is to facilitate generation of student questions, promote language development, and support understanding of the science content throughout the unit. Allowing students to ask their own questions and use their own words to make meaning of the concepts will not only help them make deep connections about science content, but will also help their oral and written language development.

Evaluate: Connecting to the Culminating Project

1. Students independently complete the Task 1 section of the Unit 1 Project Organizer in class. Revisions can be done for homework, depending upon student's needs and/or class scheduling.

2. Students have been tasked with designing a solution to prevent the impending collision of the asteroid *Etiam* with Earth. Their prompt is as follows: Today we learned that there has already been an asteroid collision in the past that had huge consequences. Use this ancient collision to justify your design solution:
    - What evidence is there that this has happened before?
    - What were the effects last time?
    - How will you use the evidence to convince the public that it is important to protect Earth from another asteroid collision?

Reflection

1. At the end of the task, ask students to reflect on what they have learned over the course of this task by answering the following three questions in their student guide:
    - At the beginning of this task, you were asked to guess what asteroid collision occurred 65 million years ago. Look back at your prediction: after collecting all the evidence today, how have you added to or changed your prediction?
    - In this task, we focused on the crosscutting concept of **Patterns**: Graphs, charts, and images can be used to identify patterns in data and these patterns can be used to identify cause-and-effect relationships. Where did you see examples of **Patterns** in this task?
    - Now that you have learned more about the fossil record and what it tells us about asteroid collisions, what questions do you still have?

2. There are no right answers, but encourage students to look back at their student guides and their class concept map. They should not change their initial responses, but rather use this reflection space to add to their ideas and questions based on what they have learned through this task. By generating more of their own questions, students continue to engage in sense-making of the phenomenon and gathering knowledge and skills for their final projects.

Assessment

1. You may collect students' Project Organizer and assess using:
   - *Criteria of your choice.* We recommend using the 3-Dimensional Assessment matrix at the beginning of this document to inform your criteria.
   - This can be a formative tool to periodically look for trends in student understanding after the completion of a task. You can then use this formative data to inform any re-teaching as necessary.

2. You may also give students time to make revisions with one of the two options:
   - Students may make changes to their Project Organizer according to your comments OR
   - Ask students to exchange Project Organizers with a partner and give partners 5 minutes to give written feedback. Then allow students time to make changes to their work according to the feedback.

Resource Card 1: Looking At Layers Of Fossils

The picture to the right shows layers of Earth, containing different fossils. Record your observations as well as your responses to the following discussion questions in the chart on your student guide:

1. Compare the layers below and above the red line. How are they different?
2. What do you think the red line represents?

Source:

- http://evolution.berkeley.edu/evolibrary/news/120501_habitatloss

Resource Card 2: Scientific Descriptions of the Soil and Fossil Data

Lucky for us, scientists have already analyzed lots of soil and fossil data, so we can also gather evidence from their observations. Read the following excerpt to find out what scientists have gathered from examining soil and fossil data:

Fossils found in soil layers of different ages show a record of slow, gradual changes in species, with simple organisms gradually being replaced by more complex organisms, because of evolutionary processes driven by natural selection.

Ever since the fossil sequence began being mapped around 1800, geologists noticed that striking "breaks" occurred in the sequence, when one group of fossilized species gave way to other groups during short intervals (just like the "break" you saw in Resource Card 1).

While this gave evidence for some sort of mass extinction, scientists were still unsure why this had happened. There are now many lines of evidence to prove that a relatively large asteroid impact happened 65 million years ago.

1. Iridium, a common component of asteroids, can be found in the 65 million year old soil layer at many points around the world. You can see it to the right as the lighter-colored rock layer.
2. The same soil layer contains grains of quartz (a type of rock) that were deformed by high shock pressures, as would occur in a giant explosion.
3. The same soil layer contains enough soot to correspond to burning down all of the forests of the world. This suggests that massive fires were touched off at the time of impact.

Record your observations of this data as well as your responses to the following discussion questions in the chart on your student guide:

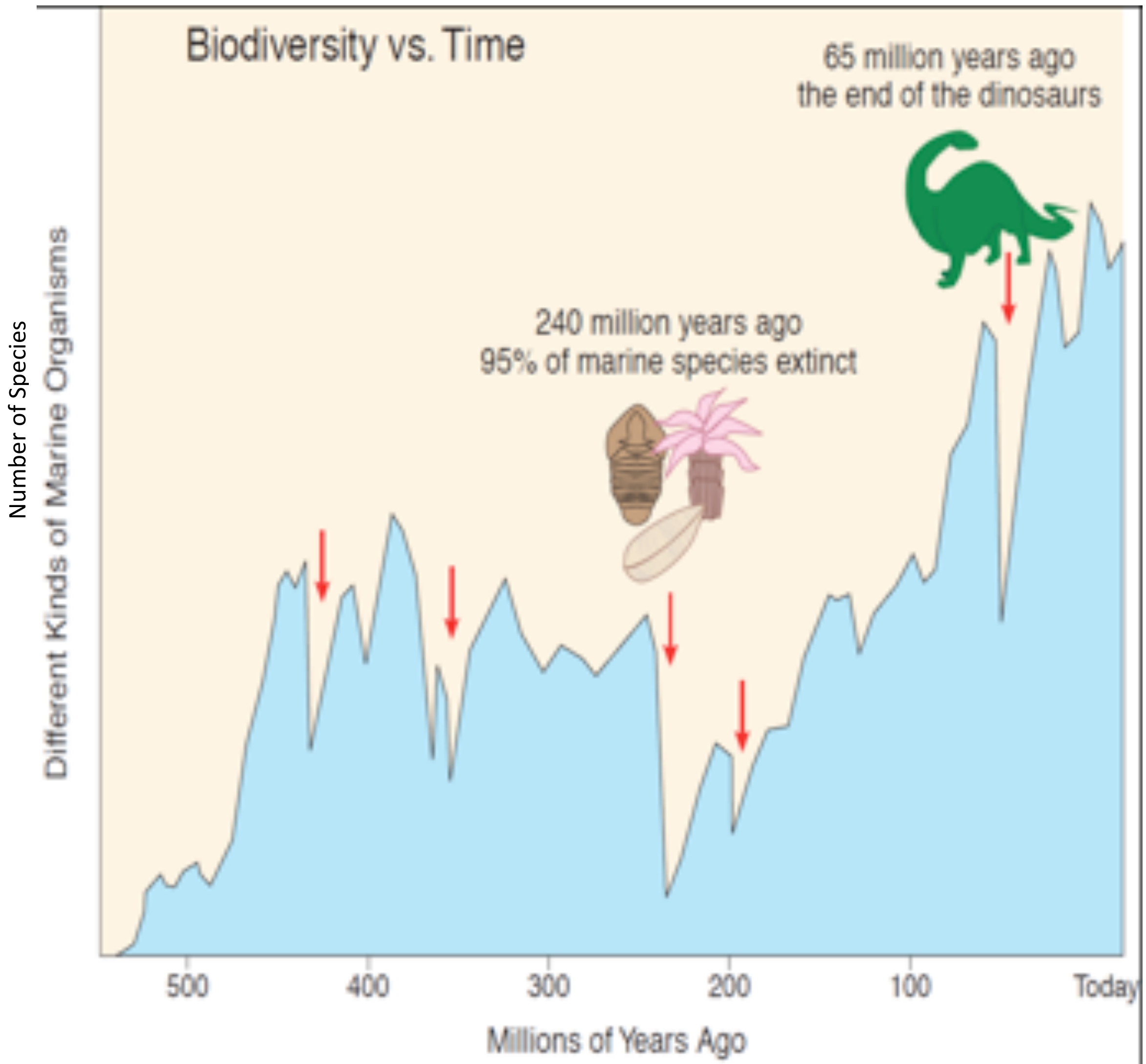
1. What fossil evidence do scientists describe in this excerpt?
2. What soil evidence do scientists give for an asteroid collision?
3. What **cause and effect** relationship can you find between the soil evidence and the fossil evidence?

Sources:

- https://www.psi.edu/epo/ktimpact/ktimpact.html
- https://www.sciencenewsforstudents.org/article/dinosaurs-extinction-asteroid-eruptions-doom

Resource Card 3: Analyzing Biodiversity Over Time

As scientists analyzed the fossil record, they took all of the data they gathered on marine organisms and created the graph below. It shows the number of different kinds of marine organisms over time.



Record your observations of this data as well as your responses to the following discussion questions in the chart on your student guide:

1. Does the number of different kinds of marine organisms stay stable over time?
2. What do the red arrows represent?
    a. What do you think are some possible causes for these dips in biodiversity?
3. The soil data showed added components in the soil layer from 65 million years ago (Resource Card 3). What do you see happening in this graph at 65 million years ago?

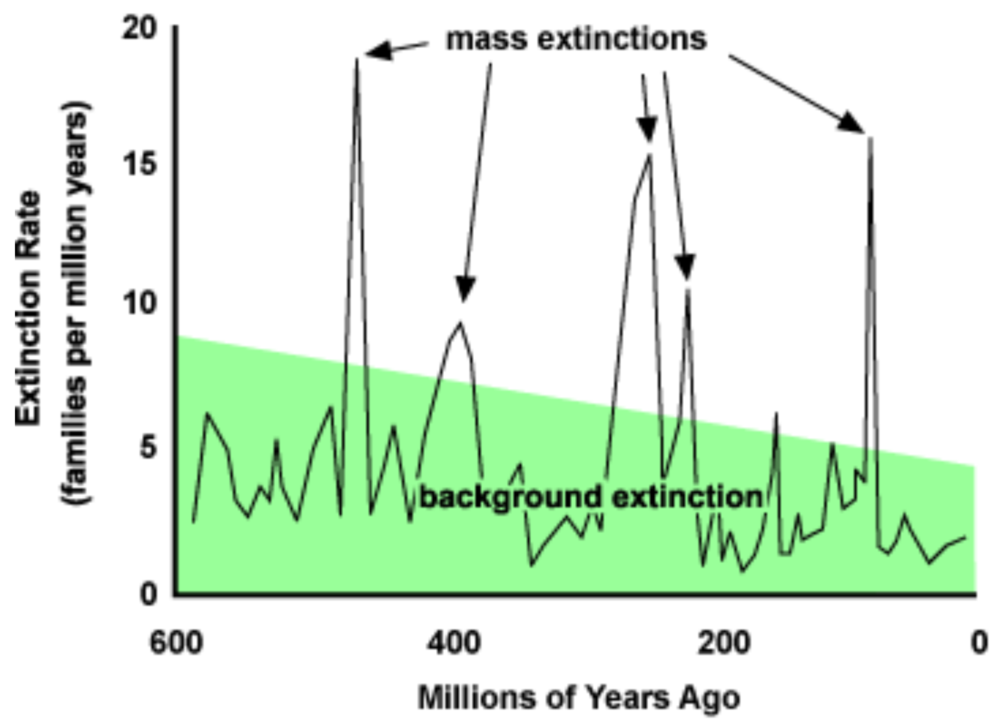
Source:

- CA NGSS document

Resource Card 4: Analyzing Extinction Rates Over Time

A paleontologist named David Jablonski was very interested in the fossil record and looking at the small and large extinctions that have occurred over time. He traveled up and down the East Coast of the U.S. looking at 65-80 million year old fossil mollusks in order to study the trickle of extinctions that go on constantly throughout Earth's history, which stand in stark contrast to catastrophic mass extinctions. Just as he was finishing this work, a new hypothesis emerged: that the mass extinction which eliminated virtually all dinosaurs 65 million years ago, was triggered by a massive asteroid slamming into Earth and scattering debris across the skies, changing the whole world's climate.

He continued to collect data on extinction patterns during the mass extinction and compare them to extinction patterns during the "normal" time that followed — his data is depicted in the graph below:



Record your observations of this data as well as your responses to the following discussion questions in the chart on your student guide:

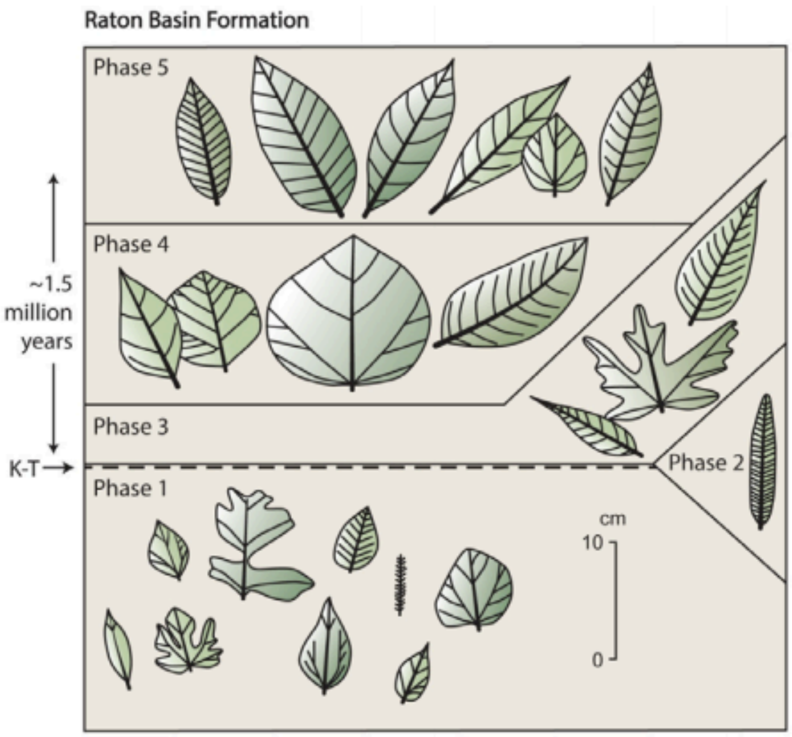
1. How does this connect to the previous graph?
    a. How is extinction connected to biodiversity?
2. What do you think the difference is between mass extinction and background extinction?
    a. Would an asteroid collision cause a mass or background extinction? Why?

Source:

- http://evolution.berkeley.edu/evolibrary/article/0_0_0/jablonski_04

Resource Card 5: Changes in Leaf Diversity 65 Million Years Ago

There is a theory that the asteroid collision that killed the dinosaurs, as well as many other species, occurred 65 million years ago. The time before is known as the Cretaceous Period (K) and the time after is known as the Teritiary Period (T). The table below shows the diversity of plants in the late Cretaceous and early Tertiary periods as determined by leaf fossils found in rock layers from the Raton Basin formation of Colorado and New Mexico. The fossils have been grouped in "phases" of changing diversity. The rock layers from the late Cretaceous, labeled Phase 1, show fossils of leaves from palm trees, Laurales (an order of flowering plants related to magnolias), and other plant species that live in tropical climates. The K-T clay layer is shown by the dotted line between Phase 1 and Phase 2. Phase 5 corresponds to about 1.5 million years after the K-T boundary.



Phase	Number of species
5	35
4	25
3	8
2	2
1	47

(Adapted from Wolfe, J. A. and Upchurch, G. A. 1987 *Proc. Natl. Acad. Sci. USA* **84**:5096-5100.)

Record your observations as well as your responses to the following discussion questions in the chart on your student guide:

1. Compare the layers above and below the dotted line. How are they different?
2. Why do you think there are less plant species after the dotted line?
    a. What may have happened at the K-T boundary?
3. Are the fossils in each layer the same as the next? If not, how do they seem to change over time?

Source:

- https://www.hhmi.org/biointeractive/weighing-evidence-mass-extinction-land

8th Grade Science Unit 1: Colossal Collisions
Task 2: Contact Forces

Unit Essential Question: *What are the effects of an asteroid collision and how can we prevent a future one?*

Introduction
Now that students have the motivation to prevent another asteroid collision, it is time for them to learn more about the scientific concepts of forces and motion in order to do so. In this task, students will investigate what factors affect the motion of objects and use this knowledge to help prevent a collision. While students can't experiment with a collision of the same scale as an asteroid collision, they can experiment with smaller models—in this case, rolling marbles and a stack of pennies. By planning and carrying out their own investigations with these everyday materials, students can leverage their experiential knowledge of objects in motion and begin to ascribe scientific concepts to these experiences. By the end of this task, students should be able to understand *Etiam's* collision with Earth within the context of mass, forces, and motion, and then use this new knowledge to brainstorm ideas on deflecting *Etiam*.

Alignment Table

Performance Expectations	Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
MS-PS2-2. Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object. [Clarification Statement: Emphasis is on balanced (Newton's First Law) and unbalanced forces in a system, qualitative comparisons of forces, mass and changes in motion (Newton's Second Law), frame of reference, and specification of units.] [Assessment Boundary: Assessment is limited to forces and changes in motion in one-dimension in an inertial reference frame and to change in one variable at a time. Assessment does not include the use of trigonometry.]	**Planning and Carrying Out Investigations** • Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim.	**PS2.A: Forces and Motion** • The motion of an object is determined by the sum of the forces acting on it; if the total force on the object is not zero, its motion will change. The greater the mass of the object, the greater the force needed to achieve the same change in motion. For any given object, a larger force causes a larger change in motion.	**Stability and Change** • Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and forces at different scales.
MS-PS2-1. Apply Newton's Third Law to design a	**Designing Solutions** • Apply scientific ideas	**PS2.A: Forces and Motion**	**Systems and System Models**

8th Grade Science Unit 1: Colossal Collisions

Task 2: Contact Forces

solution to a problem involving the motion of two colliding objects.* [Clarification Statement: Examples of practical problems could include the impact of collisions between two cars, between a car and stationary objects, and between a meteor and a space vehicle.] [Assessment Boundary: Assessment is limited to vertical or horizontal interactions in one dimension.]	or principles to design an object, tool, process or system.	• For any pair of interacting objects, the force exerted by the first object on the second object is equal in strength to the force that the second object exerts on the first, but in the opposite direction (Newton's third law).	• Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy and matter flows within systems.
MS-PS3-1. **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**. [Clarification Statement: Emphasis is on descriptive relationships between kinetic energy and mass separately from kinetic energy and speed. Examples could include riding a bicycle at different speeds, rolling different sizes of rocks downhill, and getting hit by a wiffle ball versus a tennis ball.]	**Analyzing and Interpreting Data** • Construct and interpret graphical displays of data to identify linear and nonlinear relationships.	**PS3.A: Definitions of Energy** • Motion energy is properly called kinetic energy; it is proportional to the mass of the moving object and grows with the square of its speed.	**Scale, Proportion, and Quantity** • Proportional relationships (e.g. speed as the ratio of distance traveled to time taken) among different types of quantities provide information about the magnitude of properties and processes.

Equity and Groupwork

- Discuss and come to consensus to describe collision scenarios.
- Work together to design defection strategies and plan and carry out a collision investigation.
- Discuss analysis questions to learn from each others' perspectives.

Language

- Orally present descriptions of collision scenarios.
- Interpret video resources and define main terms and laws.
- Describe a multi-step procedure.
- Write lab conclusions based on data.
- Describe graphs and mathematical relationships in words.

8th Grade Science Unit 1: Colossal Collisions

Task 2: Contact Forces

Learning Goals:

This learning task asks students to investigate how different factors affect the motion of objects and use this knowledge to help prevent a collision. More specifically, students will:

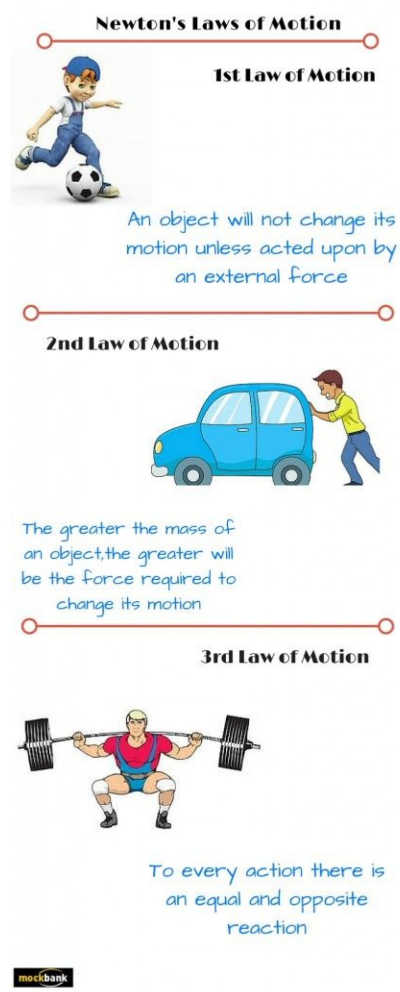
- Use their experiential knowledge to describe the reasons behind different collision scenarios.
- Design different solutions to deflect an asteroid from Earth.
- Use scientific ideas, like Newton's laws, to explain why things move.
- Plan and carry out an investigation to test different conditions of an asteroid hitting Earth.
- Apply knowledge of kinetic energy and Newton's laws to come up with ideas on deflecting an asteroid.

Content Background for Teachers

In this task, students learn about all the forces acting on objects as they move, don't move, and collide. Students experiment with these scientific concepts before learning about them explicitly, and then re-applying that new knowledge.

Specifically, students learn that a force is a push or pull upon an object resulting from the object's interaction with another object. Forces can consist of contact forces and non-contact forces. In this task, students are dealing with contact forces, which are all those types of forces that result when the two interacting objects are physically contacting each other. Some examples of this are friction, normal forces, air resistance, and applied forces. For example, in this task, a moving ball hits a stack of pennies. The force of the ball hitting the stack of pennies would be an applied force.

In this same scenario of a ball hitting (or not hitting) a stack of pennies, students can also apply Newton's three laws. Newton's first law states that an object at rest stays at rest and an object in motion stays in motion with the same speed and direction unless acted upon by an unbalanced force. In other words, the pennies will stay stationary until the force of the ball sets them in motion. Newton's second law states that the acceleration of an object is dependent on both the net force acting upon the object and the mass of the object. This is what students examine in the Elaborate portion of the task, and they find that a greater mass will increase the force of the rolling ball. Related to this experiment, students also learn that the kinetic energy of an object, or the energy due to its motion, is dependent on the mass of that object. By graphing data, they will see that the relationship is proportional. Students will also graph and see the relationship with speed in that the kinetic energy of an object grows with the square of its speed. Lastly, Newton's third law states that for every action, there is an equal and opposite reaction. Students will see this firsthand, as the ball bounces backward once it collides with the pennies.



https://www.pinterest.com/pin/52917364350091

By understanding these scientific concepts of forces and motion within the context of this small model—the ball and the pennies—students will be able to apply these scientific concepts to the bigger problem they are addressing—the asteroid collision. Not only does this task help them explain the scientific nature of the asteroid movement and collision, it will also help them start thinking about how they can use these scientific concepts to thwart the collision.

Academic Vocabulary

- Trajectory
- Trial
- Control
- Dependent Variable
- Independent Variable
- Procedure
- Mass
- Kinetic Energy
- Speed
- Force
- Newton's First Law
- Newton's Second Law
- Newton's Third Law

Time Needed (Based on 45-Minute Periods)

5 Days

- Engage: 0.5 period
- Explore: 1 period
- Explain: 0.5 period
- Elaborate: 2 periods
- Evaluate and Reflection: 1 period

Materials

- Unit 1, Task 2 Student Version

Explore (per group)

- Stack of 40 pennies (Earth)
- Heavy ball or large marble (asteroid *Etiam*)
- A track for *Etiam's* trajectory (pipe insulation tubing, cut in half lengthwise)
- Risers (4 textbooks)
- Ruler
- String
- Balls of varying mass (Recommended: http://www.arborsci.com/physics-balls, but if not, use marbles of different size and mass)
- Foam
- Rubberbands
- Popsicle sticks
- Plastic spoons
- Tape

Explain

- Projector and speakers
- Tablets/computers
- Headphones (optional)

Elaborate

- Stack of 40 pennies (Earth)
- A track for *Etiam's* trajectory (pipe insulation tubing, cut in half lengthwise)
- Risers (4 textbooks)
- Ruler
- Marbles of varying mass (see recommendation above)
- Calculators (Optional)

Evaluate

- Project Organizer Handout

<u>Instructions</u>

Engage

1. Introduce Task 2: In Task 1, you learned about a historical asteroid collision that had big consequences. Think about what you were still wondering about at the end of the last task (look back if you need to). What questions do you still have?
    - Before you pass out their student guide, give students time to reflect individually or with a partner about the questions they recorded at the end of the last task. Share a few of these out as a class, using facilitating questions to guide students toward questions that relate to this task.

2. Transition to Task 2: Now that you know why it's so important we protect against another asteroid collision, it's time to figure out how we might do it. To do this, let's look more closely at what might happen when other things collide.
    - Now pass out their Task 2 student guide.

3. Students are given a series of scenarios to examine (below). For each scenario, ask students to use their own knowledge to explain why they think these happen as best they can. This not only introduces content by activating experiential knowledge, it also introduces students to one of the crosscutting concepts focused on in this task.
    - Students engage with **Systems and System Models** as they draw diagram models of each scenario to represent the system at work.
    - This activity should be done in partners, but each student should be individually recording their descriptions in their own student guides.
    - The scenarios can either be read aloud or projected for students to see (or both). The scenarios are as follows:
        - A moving soccer ball gets kicked.
        - A rocket launches from earth, leaves the atmosphere, and goes into space.
        - You are standing in a bus that stops suddenly, and you keep moving/falling forward.
        - A comet in space continues to move without slowing down or speeding up.

- A large asteroid crashes into the moon.
- A small asteroid crashes into the moon.

4. Recommended: Ask students to be prepared to share their descriptions of the scenarios. When calling on pairs of students to share their description of a scenario, it is recommended that you call on pairs using equity sticks. This encourages more equitable participation in class-wide discussions (See "How to Use This Curriculum" for more details)

Explore

1. We recommend reading the introduction on their student guides aloud and projecting the set-up diagram and materials list to review as a class. This allows students to understand the context of the activity and what each part of the model represents. In this activity, students will be using a smaller model to help them design ways they might save the Earth from an impending collision with the asteroid *Etiam*.
   - This activity emphasizes the crosscutting concept of **Stability and Change** as students examine the forces involved in the prevention of a collision at a much smaller scale in order to inform their explanation of stability and change in a much larger system—an asteroid collision.

2. Assign roles to each group. You may use whatever roles you prefer. We recommend the use of the Materials Manager, Facilitator, Harmonizer, and Reporter.
   - Ask Facilitator to read the directions and to make sure everyone understands the task.
   - Ask the Materials Manager to handle any resources needed to complete the task.
   - Ask the Harmonizer to make sure that everyone contributes their ideas and that everyone's voice is heard.
   - Ask the Reporter to make sure the group is recording their setup, observations, and reasoning in their student guides and reporting all the necessary information for the final poster.

3. The nature of this exploration is very open, allowing students the freedom to try all kinds of ideas as a part of the process of **Designing Solutions.** In alignment with this SEP, students should use any scientific ideas they already have about forces and motion as well as relevant experiences to inform the design of their collision prevention.
   - In groups, students will try a number of different strategies in order to attempt to deflect "*Etiam*." For each attempt, they should record both their observations and their reasoning of why they think objects moved the way they did.
   - Possible attempts might include blocking the asteroid, changing the asteroid's course, slowing the asteroid down, changing the size of the asteroid, etc.

4. After students have implemented and recorded all their attempts, have them make a poster showing and explaining their best deflection strategy. This reinforces the crosscutting concept of **Systems and System Models**, as students use models to represent their deflection system. As students learn more about forces and motion, they will be able to identify explicit interactions and flows of energy. These can then be used for their culminating projects.
   - Groups should briefly present these posters, so the class gets an idea of the different solutions out there. You may also want to collect this as a formative assessment to identify trends in students' ability to design solutions or use a model to represent a system. See "How to Use This

Curriculum" for strategies on utilizing formative assessment data to provide feedback to students and inform classroom instruction.
  - *Optional*: students slow-motion record their best deflection strategy. We greatly encourage this, as many will choose to use this video in their news segment.

Explain

1. This section of the task takes what students experienced in the Explore lab and ascribes scientific concepts—specifically forces and Newton's laws.

2. It is recommended that you begin this portion of the task with a class-wide **KWL** (what do you **K**now, what do you **W**onder, what did you **L**earn?) chart about force. Call on students to share ideas and questions for the **K** and the **W** portions and record on the class chart**.**

3. Project the video, "What is Force?": https://www.youtube.com/watch?v=GmlMV7bA0TM
   - In the video, the host asks people on the street to define force. They seem to have trouble defining it, even though they appear to have an idea of what force does. *Stop the video here.* Have students share, first in pairs, then as a whole class, what their definition of force is. Again, use equity sticks to call on students.
   - After, resume the video for the reveal: A force is a *push or pull*. Have students record this in the chart on their student guides.

4. Distribute computers/ipads for students to watch the other videos on Newton's laws. If these are not available, use the same video projection format as the previous video.
   - You may choose one or both of the following videos for students to watch
     - *Tiros Educational - Newton's Laws of Motion and Forces*
       - https://www.youtube.com/watch?v=NYVMlmL0BPQ
     - *Makemegenius. Newton's 3 (three) Laws of Motion*
       - https://www.youtube.com/watch?v=mn34mnnDnKU
     - For students who are particularly interested in football, the National Science Foundation also has videos about the science of NFL football as it relates to Newton's laws. These can be accessed on YouTube.
   - Students should fill out the graphic organizer in their student guides, making sure to not only record a definition, but also an example and diagram.
     - This will help them to describe the asteroid collision within the context of these laws.
     - As students fill out their charts, you may wish to formatively assess students with some of the following questions: What is the relationship between force and motion? What is the difference between equal and unequal forces? What is a scenario where forces are equal? How do unequal forces affect motion? What is a scenario where forces are unequal?

5. Debrief as a class, by adding to the **L** column in the class **KWL.**
   - It is recommended that you facilitate connections of the newly learned vocabulary to the Explore Lab. Some options are:
     - Think-Pair-Share about how the videos help explain phenomena that occurred in the lab. Use equity sticks to equitably share out ideas.

    - Provide a diagram of the lab in action and have students write in labels of where Newton's Laws occurred.
    - If students recorded slow-motion videos in the Explore, have them work on voiceovers using academic language of Newton's Laws.
  - These can all be used as formative assessments to see trends in student understanding of the DCIs related to Newton's Laws. See "How to Use This Curriculum" for strategies on utilizing formative assessment data to provide feedback to students and inform classroom instruction.

Elaborate

1. This section of the task asks students to take all of their experiential and scientific knowledge around forces and motion and combine it within an investigation related to the relationship between mass and force.
    - This part of the task asks students to use the Science and Engineering Practice of **Planning and Carrying Out Investigations**. In the design, students identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, etc.

2. Assign roles to each group. You may use whatever roles you prefer. We recommend the use of the Materials Manager, Facilitator, Harmonizer, and Recorder.
    - Ask Facilitator to read the directions and to make sure everyone understands the task.
    - Ask the Materials Manager to handle any resources needed to complete the task.
    - Ask the Harmonizer to make sure that everyone contributes their ideas and that everyone's voice is heard.
    - Ask the Recorder to make sure the group is recording their experiment design, data, and analysis.

3. In this investigation, similar materials are provided as the Explore, but now the focus is not to attempt to deflect the asteroid, but rather just to determine how "asteroids" with different masses impact "Earth." During their investigation, a stack of pennies will represent Earth and a set of rolling objects will represent *Etiam*.
    - As a class, review the experimental question as well as the list of possible materials.

4. In groups, students will use the planning questions to help them plan their investigation.
    - Students must get their experimental design cleared before they may continue with the experiment. When checking experimental designs, ensure that students have created an experiment that tests how marbles of different types affects the number of pennies knocked down. Everything else should be controlled.

5. Once students have run their experiments, they should record their data in the data table provided and answer the analysis questions in their student guides.
    - Based on student need, you may choose to help students fill in the blanks on their data table (pictured below):

Data Table 1: Change in ball type

	# pennies knocked over in each trial					
Type of rolling object	**Trial 1**	**Trial 2**	**Trial 3**	**Trial 4**	**Trial 5**	**Average # of pennies knocked from stack**

6. To help students better process all the concepts they have been exploring, conduct a facilitated discussion with a class-wide demo of the above experiment. We recommend the use of Think-Pair-Shares and equity sticks to create a richer discussion and more equitable participation (See "How to Use This Curriculum" for more details).
   - Set up the experiment and run it with one type of ball first. Some facilitating questions to ask may be:
     - What kind of energy does the ball have while in motion?
     - What are all the different forces acting on the pennies?
     - Where do we see Newton's first law happening?
     - Where do we see Newton's third law happening?
   - Run the experiment again with a ball of different mass. You may ask the same facilitating questions above for reinforcement, but we also recommend asking the following facilitating questions:
     - How are the balls different?
     - What differences did you notice when you changed the type of ball?
     - Why do you think this happened?
     - How does this show Newton's second law?

7. Analysis questions specifically connect the experiment results to the scientific concepts learned in the Explain. Because of the class-wide discussion above, students may be prepared to answer the questions individually, if you wish to use them as a form of formative assessment. However, because there are many concepts in this task, we recommend having students complete these questions in pairs or small groups.
   - 1: The pennies are at rest until a force acts on the object, in this case the ball hitting the pennies. This represents Newton's first law.

- This question emphasizes the crosscutting concept of **Stability and Change** by asking students to examine how forces in the experiment affect the stability and change of objects.

- 2: After a ball hit the pennies, it would bounce back. This matches Newton's third law, which says that for every action, there is an equal and opposite reaction. The action of the ball transferring motion to the pennies corresponds with the reaction of the ball bouncing back.
- 3: When the ball had more mass, more pennies were knocked over.
- 4a: Students should draw two line graphs of the data and describe the relationship between mass and kinetic energy and the relationship between speed and kinetic energy. Students should notice that kinetic energy is proportional to the mass of the object (a ratio of 200/1) and kinetic energy grows with the square of its speed.
    - This question asks students to use the Science and Engineering Practice of **Analyzing and Interpreting Data** as they construct and interpret graphical displays to identify linear and nonlinear relationships.
- 4b: Balls with more mass knock over more pennies because they have more kinetic energy to be passed to the pennies they hit. Thus, if *Etiam* has a lot of mass, it has a lot more kinetic energy that it will pass on to Earth, thus doing a lot more damage.
    - This question emphasizes the crosscutting concept of **Scale, Proportion and Quantity** as students use the proportional relationship between different types of quantities (mass and energy) to provide information they can use for the larger-scale event of an asteroid collision.

8. Return to the whole-class concept map from the Lift-Off Task.
    - In small groups, have students brainstorm new concepts and new connections that they have learned in this task, as well as any new questions that have come up for them. Then have groups share these aloud in a class-wide discussion and add to the class concept map. The use of equity sticks is encouraged for more equitable participation in class-wide discussions (See "How To Use This Curriculum" for more details).
        - Some facilitating questions to ask students are: What new ideas/concepts do you want to add to the map? What connections do you want to add or change? What is your reason for that addition/revision? What connections can we make between the questions/ideas already on the map? What new questions do you have about the phenomenon?
        - Draw circles around each question and boxes around each concept.
        - Write connector words to describe connections between the concept boxes.
        - For this task, students may begin to connect some of their previous question circles to concept boxes about the following: contact forces, Newton's laws, mass, speed, and kinetic energy.
    - Have students analyze the additions to the class concept map for as many examples of this task's crosscutting concepts as they can find. Once a student has identified the crosscutting concept, you can trace the circle in the corresponding color (decided on in the Lift-Off task). We recommend asking students to share key words that helped them identify the crosscutting concept for that concept or question. Some identifying words students might look for are:
        - **Scale, Proportion, and Quantity**: These could be phrases such as, "is proportional to", "compared to", "has a ratio of", "is bigger/smaller than", "is longer/shorter than", etc.

 - **Systems and Systems Models**: These could be phrases such as, "is a part of," "is related to," "consists of," "interacts with," "works together with," etc.
 - **Stability and Change**: These could be phrases such as, "remains the same", "is changed by", "is disrupted by", "changes", "disrupts", etc.
- Once again, the purpose of this concept map is to facilitate generation of student questions, promote language development, and support understanding of the science content throughout the unit. Allowing students to ask their own questions and use their own words to make meaning of the concepts will not only help them make deep connections about science content, but will also help their oral and written language development.

Evaluate: Connecting to the Culminating Project

1. Students independently complete the Task 2 section of the Unit 1 Project Organizer in class. Revisions can be done for homework, depending upon student's needs and/or class scheduling.

2. Students have been tasked with designing a solution to prevent the impending collision of the asteroid *Etiam* with Earth. The student prompt is as follows: In this task, you explored and studied how different contact forces and factors like mass help predict the motion of objects. Now, let's use these ideas to start deciding how to deflect *Etiam* from its path towards Earth.
   - How will Etiam's large mass affect Earth? Use experimental evidence from the task as well as scientific ideas of mass, kinetic energy, and speed to back up your response.
   - How can Newton's three laws help us predict and explain what will happen when *Etiam* hits Earth?
   - Record ideas you have on deflecting *Etiam*, using the following questions to help you:
     - In the experiments, which solutions worked best?
     - Based on the data, can you combine characteristics from the best solutions to create an even better one?
     - How does each solution use contact forces and your understanding of mass and motion?

Reflection

1. At the end of the task, ask students to reflect on what they have learned over the course of this task by answering the following three questions in their student guide:
   - At the beginning of this task, you attempted to explain why different scenarios happen the way they do. Look back at your responses: after learning everything you have about contact forces, how can you add to or revise your explanations? Use information from the task to better explain these scenarios with the new scientific ideas we learned today.
   - In this task, we focused on the crosscutting concepts of: **Scale, Proportion, and Quantity**: There are proportional relationships between different types of quantities; **Systems and System Models**: Models can be used to represent systems and their interactions; and **Stability and Change:** We can examine forces at different scales to explain stability and change. Where did you see examples of **Scale, Proportion, and Quantity, Systems and System Models**, and **Stability and Change** in this task?
   - Now that you have learned more about the contact forces that are involved in an asteroid collision and preventing an asteroid collision, what questions do you still have?

2. There are no right answers, but encourage students to look back at their student guides and their class concept map. They should not change their initial responses, but rather use this reflection space to add to their ideas and questions based on what they have learned through this task. By generating more of their own questions, students continue to engage in sense-making of the phenomenon and gathering knowledge and skills for their final projects.

Assessment

1. You may collect students' Project Organizer and assess using:
   - *Criteria of your choice.* We recommend using the 3-Dimensional Assessment matrix at the beginning of this document to inform your criteria.
   - This can be a formative tool to periodically look for trends in student understanding after the completion of a task. You can then use this formative data to inform any re-teaching as necessary.

2. You may also give students time to make revisions with one of the two options:
   - Students may make changes to their Project Organizer according to your comments OR
   - Ask students to exchange Project Organizers with a partner and give partners 5 minutes to give written feedback. Then allow students time to make changes to their work according to the feedback.

8th Grade Science Unit 1: Colossal Collisions

Task 3: Gravity – A Non-Contact Force

Unit Essential Question: *What are the effects of an asteroid collision and how can we prevent a future one?*

Introduction

In the last task, students explored different contact forces that have an effect on how objects move and collide. However, there is another less tangible force that also affects how objects move and collide—gravity. In this task, students use a model to begin thinking about their own prior knowledge and experience with gravity, mostly their understanding that gravity pulls objects down towards Earth. In order for students to be able to thwart an asteroid collision, they will have to delve deeper than this basic understanding. As students collect information from three different resources, they will find that gravity does not just attract objects towards Earth, but also towards other bodies, and that this attraction has everything to do with an object's mass. By the end of this task, students will be able to dispel some common misconceptions about gravity and use their new understanding to brainstorm more ways to prevent the collision of *Etiam* with Earth.

Alignment Table

Performance Expectations	Scientific and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
MS-PS2-4. Construct and present arguments using evidence to support the claim that gravitational interactions are attractive and depend on the masses of interacting objects. [Clarification Statement: Examples of evidence for arguments could include data generated from simulations or digital tools; and charts displaying mass, strength of interaction, distance from the Sun, and orbital periods of objects within the solar system.] [Assessment Boundary: Assessment does not include Newton's Law of Gravitation or Kepler's Laws.	**Engaging in Argument From Evidence** • Construct and present oral and written arguments supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem.	**PS2.B: Types of Interactions** • Gravitational forces are always attractive. There is a gravitational force between any two masses, but it is very small except when one or both of the objects have large mass—e.g., Earth and the sun.	**Systems and System Models** • Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy and matter flows within systems.
Equity and Groupwork • Work in specific group roles to analyze resources. • Discuss and record ideas from other group members.			
Language • Gather information from video and textual resources and record written notes. • Record observations in words and pictures.			

- Orally share conclusions about gravity.
- Construct a written argument supported by evidence.

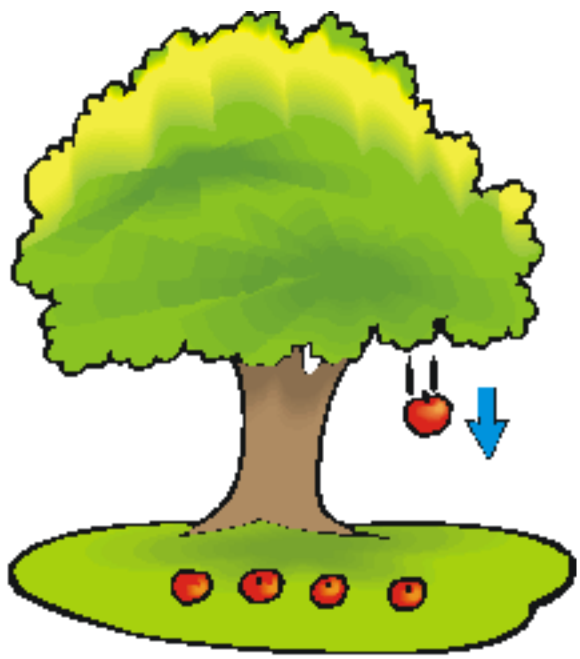
Learning Goals

This learning task asks students to gather evidence of how gravitational interactions are attractive and depend on the masses of interacting objects. More specifically, the purpose is to:

- Use a model to engage prior knowledge and experiences of gravity.
- Analyze evidence about gravity, specifically its relationship with mass.
- Explain what gravity is and how mass affects gravitational force, using examples.
- Construct an argument that uses evidence to dispel a misconception about gravity.
- Apply knowledge of gravity to brainstorm solutions to thwart an asteroid collision.

Content Background for Teachers

By this grade level, most students understand that gravity is a force of attraction—the force that keeps them on the ground and causes objects to fall. However, most students' understanding of gravity is set within the context of Earth, rather than the solar system as a whole, which is what they will need to understand if they are to thwart the collision of *Etiam* with Earth in their Culminating Project.



http://idahoptv.org/sciencetrek/topics/gravity/facts.cfm

We can define gravity as a force that pulls objects towards each other. Centuries ago, Sir Isaac Newton was sitting under a tree when an apple fell and hit him on the head. This led him to ask the following questions: Why should an apple always fall perpendicularly to the ground? Why should it not go sideways or upwards? He soon hypothesized that there was some invisible force that was pulling all objects towards the center of the Earth. Students often conceptualize this as "what comes up must come down", which is technically true. However, what they really mean by "down" is that there is a gravitational pull attracting objects "towards" the center of the Earth.

This idea of objects being attracted towards Earth only applies when the objects are on or near Earth's surface and have a smaller mass than Earth. What may be new to students in this task is that Earth is not the only body that has gravity. Each body with a large mass also has its own gravitational field. For example, when an object gets far enough away from Earth's gravity and close to the moon's gravity, that object will be attracted towards the center of the moon. This is a concept that students will be able to apply when they think about the trajectory of *Etiam*.

Another gravity-related concept that may be newer for students is that the greater an object's mass is, the greater the effect of its gravity. In this task, students will look at data that shows them how the masses of different planets affects the gravitational force on those planets. This will also affect how they think about interfering with *Etiam*'s collision with Earth.

Academic Vocabulary

- Gravity
- Attraction
- Mass
- Gravitational pull
- Orbit

Time Needed (Based on 45-Minute Periods)

4 - 5 Days

- Engage: 0.5 period
- Explore: 1-2 periods
- Explain: 1 period
- Elaborate: 0.5 period
- Evaluate and Reflection: 1 period

Materials

- Unit 1, Task 3 Student Version

Engage

- 2 shallow pans or trays with edges
- Sand (to fill pans with)
- Two balls of different mass, but same size (we recommend a Styrofoam or wood ball and a steel ball – see the following website for examples: http://www.arborsci.com/physics-balls)

Explore

- Resource Cards 1-3 (1 copy of each per group)
- Computers or tablets (1 per group)

Explain

- Projector and Speakers

Evaluate

- Project Organizer Handout

Instructions

Engage

1. Introduce Task 3: In Task 2, you explored the obvious forces acting on objects as they move, don't move, and collide. Think about what you were still wondering about at the end of the last task (look back if you need to). What questions do you still have?
    - Before you pass out their student guide, give students time to reflect individually or with a partner about the questions they recorded at the end of the last task. Share a few of these out as a class, using facilitating questions to guide students toward questions that relate to this task.

2. Transition to Task 3: Today, you will look at a less tangible force that also affects the collision course of the asteroid, *Etiam*.
    - Now pass out their Task 3 student guide.

3. Introduce the Crater demo to students by reading the second paragraph on their student guide aloud. In this model, the sand will represent Earth and the ball will represent *Etiam*. Conduct the demo using the materials outlined in the Materials section.
    - Fill two pans with sand and place on the ground. Hold the light ball and heavy ball above each of the trays from the same height (waist to chest height is sufficient). Drop the balls at the same time.
    - Have students discuss their observations and analyses in pairs and answer questions #1-4 on their student guide. Then use equity sticks to share out responses to the questions (See "How to Use This Curriculum" for more information)
    - The purpose of this activity is to expose students to gravity within the context of a model of their culminating project—an asteroid collision. Students should observe that when the same-size balls were dropped, they fell at the same time, but different-sized craters were created in the sand. This is because all objects free fall with the same acceleration, due to gravity. In accordance with Newton's second law, the crater is larger for the ball with larger mass because the greater mass caused it to fall with greater force. While students may not explicitly articulate these scientific concepts at this point, they should be able to make experiential observations and connections to motion and gravity.

4. Question 5 asks students to think about other examples of gravity from their daily life.
    - They can discuss these with their group members and record in their student guide.
        - Optional: pose some of your own scenarios that elucidate some of the misconceptions around gravity. For example: a water bottle sitting on a table. Is this an example of gravity? Standing on Earth: is this an example of gravity?

Explore

1. In this section of the task, students utilize three different resources to collect more information about gravity.

2. Pass out the three resource cards to each group, as well as a computer or tablet. Then assign roles to each group. You may use whatever roles you prefer. We recommend the use of the Materials Manager, Facilitator, Harmonizer, and Recorder.
    - Ask Facilitator to read the directions and to make sure everyone understands the task.
    - Ask the Materials Manager to handle any resources needed to complete the task.
    - Ask the Harmonizer to make sure that everyone contributes their ideas and that everyone's voice is heard.
    - Ask the Recorder to make sure the group is recording their findings in their student guides.

3. Students analyze the resource cards at their own pace, drawing pictures to show what they learn about gravity and answering the discussion questions provided. The purpose of these discussion questions is to guide students towards an understanding of gravity as an attractive force that is dependent on the mass

of an object. The goal of drawing pictures is so students can represent the systems they are observing as models, showing how changing inputs affects outputs. This emphasizes the crosscutting concept of **Systems and System Models.**

- The first and third resources provide students with models they can replicate and analyze.
- The second and third resources ask students to explore components of these systems, specifically how mass affects the gravitational pull between parts of the system.
    - Optional: For Resource Card 2, have students time their own rock drop from a height of 10 meters to get a feel for how scientists collected that data.
- Optional: You may want to show students how to draw larger force arrows to depict larger forces in a diagram, as shown in the computer simulation model (Resource 3).

Sample information Collection Chart

	Draw pictures to show what the resource tells/shows you about gravity	**Discussion Questions**
Resource 1: Video Model	*Students should draw a diagram that shows the following: There is a gravitational pull that holds the alien to the planet. When he jumps far enough away from the planet and gets closer to the other planet, he enters that planet's gravitational field. Thus, he is attracted to the other planet.*	1. What force keeps the pink and blue alien attracted to the planet he is first sitting on? *Gravity* 2. When he first tries to jump to the other planet, what happens? Why do you think this happens? *He gets pulled back toward the first planet because the gravitational pull towards his planet is strongest as he is nearest to it.* 3. Why do you think he is finally able to move to the other planet? What keeps him on the other planet? *He is able to get closer to the other planet and thus that planet's gravitational pull is stronger.*
Resource 2: Data Set	*Students should draw a diagram that shows the following: The greater the mass of the body, the quicker a 1 pound rock is able to fall to its surface. This means that the greater the mass of the body, the stronger the gravitational pull.*	1. Which body has the largest mass? *The sun* a. How does the time it takes for a rock to reach that body's surface compare to others? *It is the shortest amount of time.* 2. Take a look at the right-hand column. If the time is shorter, does that mean the gravitational pull is stronger or weaker? *The shorter the time, the stronger the gravitational pull.* 3. Now compare the two right-hand columns. Write a rule that compares mass of the body and gravitational pull. Optional sentence stem: The _____ the mass of the body, the ____ the gravitational pull. *The greater the mass of the body, the stronger the gravitational pull.*

8th Grade Science Unit 1: Colossal Collisions

Task 3: Gravity – A Non-Contact Force

Resource 3: Computer Simulation Model	*Students should draw a diagram that shows the following: When the mass of the Earth or Sun increases, the gravitational force increases. And vice versa.*	Part 1: 1. How does the mass of the Sun impact the orbit of Earth? *It determines how close the Earth orbits the sun.* 2. What would happen if the mass of the Sun increased? *It would attract Earth closer to the Sun.* 3. What would happen if the mass of the Sun decreased? *Earth would drift farther away from the Sun rather than staying attracted in an orbit.* Part 2: 1. How would you describe the Moon's movement? *It orbits in a circle around the Earth.* 2. What would happen to the Moon if the Earth's mass decreased? *It is no longer attracted to the Earth and drifts away.* 3. What would happen to the Moon if the Earth's mass increased? *It is extremely attracted to Earth and collides with it.*

Explain

1. Now that students have used models and data to gather more information on gravity, it is time for them to put it all together.

2. First, students summarize what they learned from the Explore in the first two columns of a KWL chart (Know and Want to Know).
    - This may be done individually, in pairs, or in groups. However, we recommend it be done individually since student knowledge may vary.
    - It is recommended you ask students to share out a few of their "Knows" and "Want to Knows" with the class, using equity sticks for more equitable participation.

3. Project the following video on gravity that will help to summarize some of the concepts students learned through the resources: https://www.youtube.com/watch?v=EwY6p-r_hyU ?. Stop the video at 10:25.
    - Students fill in the "Learned" section of their KWL chart individually, before discussing their understandings with group members.
    - After students discuss with their group members, have them add new understandings to the "Learned" section of their KWL chart.
    - It is recommended you also summarize these points in a class-wide discussion.

4. Lastly, students will draw two conclusions about gravity: how they would define it and how mass affects gravitational force. In both cases, students are asked to use examples from the information they have collected to back up their descriptions. This can be done in their groups as well.

Elaborate

1. Now that students have explored and explained gravity, they should be ready to tackle a common misconception. The Elaborate outlines a scenario in which two friends are arguing about how astronauts on the moon avoid floating away into space.
    - Friend 1 says the astronauts must have a cord tied to them at all times in order to avoid floating away into space. Friend 2 says the astronauts must always wear heavy boots to avoid floating away into space.
    - Because students have now learned about the gravitational pull of other bodies like the moon, through many different resources, they should be able to explain to their friends that the moon's gravity is what keeps the astronauts from floating away.
    - Here students are using the Science and Engineering Practice of **Engaging in Argument From Evidence**, as they construct an accurate argument that refutes both of their friends' arguments, using evidence and scientific reasoning from the rest of the task.

2. We encourage students to do this independently, since this is a good opportunity for formative assessment. Collect student work and identify trends in students' ability to construct an accurate argument using evidence and reasoning. See "How to Use This Curriculum" for strategies on utilizing formative assessment data to provide feedback to students and inform classroom instruction.

3. Return to the whole-class concept map from the Lift-Off Task.
    - In small groups, have students brainstorm new concepts and new connections that they have learned in this task, as well as any new questions that have come up for them. Then have groups share these aloud in a class-wide discussion and add to the class concept map. The use of equity sticks is encouraged for more equitable participation in class-wide discussions (See "How To Use This Curriculum" for more details).
        - Some facilitating questions to ask students are: What new ideas/concepts do you want to add to the map? What connections do you want to add or change? What is your reason for that addition/revision? What connections can we make between the questions/ideas already on the map? What new questions do you have about the phenomenon?
        - Draw circles around each question and boxes around each concept.
        - Write connector words to describe connections between the concept boxes.
        - For this task, students may begin to connect some of their previous question circles to concept boxes about the following: gravity and mass.
    - Have students analyze the additions to the class concept map for as many examples of this task's crosscutting concept as they can find. Once a student has identified the crosscutting concept, you can trace the circle in the corresponding color (decided on in the Lift-Off task). We recommend asking students to share key words that helped them identify the crosscutting concept for that concept or question. Some identifying words students might look for are:
        - **Systems and Systems Models**: These could be phrases such as, "is a part of," "is related to," "consists of," "interacts with," "works together with," etc.
    - Once again, the purpose of this concept map is to facilitate generation of student questions, promote language development, and support understanding of the science content throughout the unit. Allowing students to ask their own questions and use their own words to make meaning

of the concepts will not only help them make deep connections about science content, but will also help their oral and written language development.

Evaluate: Connecting to the Culminating Project

1. Students independently complete the Task 3 section of the Unit 1 Project Organizer in class. Revisions can be done for homework, depending upon student's needs and/or class scheduling.

2. Students have been tasked with designing a solution to prevent the impending collision of the asteroid *Etiam* with Earth. Their prompt is as follows: In this task, you learned about another, less tangible force that also affects the motion of *Etiam*. Look back at the trajectory of *Etiam* from your Culminating Project handout and brainstorm where this force may help you prevent *Etiam's* collision with Earth.
    - Draw a diagram showing how gravity is currently influencing *Etiam.*
    - What other objects in our solar system might influence *Etiam's* movements as it travels through space? Why?
    - Illustrate moments in *Etiam's* trajectory where the asteroid might be impacted by other gravitational forces in a way that changes its trajectory.
        - Explain how this works.

Reflection

1. At the end of the task, ask students to reflect on what they have learned over the course of this task by answering the following three questions in their student guide:
    - At the beginning of this task, you predicted why objects fall down towards Earth. Look back at your initial response: after learning everything you have about gravity, how can you make your response more specific? What other details have you learned about gravity?
    - In this task, we focused on the crosscutting concept of **Systems and System Models:** Models can be used to represent systems and their interactions. Where did you see examples of **Systems and System Models** in this task?
    - Now that you have learned more about how gravity may be involved in an asteroid collision and preventing an asteroid collision, what questions do you still have?

2. There are no right answers, but encourage students to look back at their student guides and their class concept map. They should not change their initial responses, but rather use this reflection space to add to their ideas and questions based on what they have learned through this task. By generating more of their own questions, students continue to engage in sense-making of the phenomenon and gathering knowledge and skills for their final projects.

<u>**Assessment**</u>

1. You may collect students' Project Organizer and assess using:
    - *Criteria of your choice.* We recommend using the 3-Dimensional Assessment matrix at the beginning of this document to inform your criteria.
    - This can be a formative tool to periodically look for trends in student understanding after the completion of a task. You can then use this formative data to inform any re-teaching as necessary.

2. You may also give students time to make revisions with one of the two options:
    - Students may make changes to their Project Organizer according to your comments OR
    - Ask students to exchange Project Organizers with a partner and give partners 5 minutes to give written feedback. Then allow students time to make changes to their work according to the feedback.

Resource Card 1: A Video Model

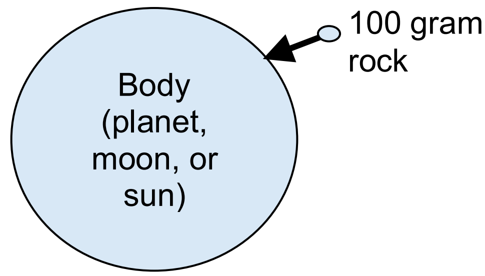
Instructions:

- Watch the following video in your small groups (sound is not required):
  - https://www.youtube.com/watch?v=4sKqz5JQt5o
- Analyze and discuss the video with your group members and use it to answer the questions in your student guide.

Resource Card 2: Data Set

We experience gravity all the time. It's why things fall when we drop them and why we do not fly into space. Gravity is a force that acts the same way everywhere in the universe. But what **properties** of an object affect the **strength** of its gravitational force?

To investigate the strength of gravity on different bodies (planets, moons, or suns), NASA scientists have studied how long it would take a 100-gram rock to fall 100 meters to the surface of each major body in our solar system. They recorded their data in the table below.



Instructions:

- Analyze and discuss the data with your group members and use it to answer the questions in your student guide.

Table 1: Time it Takes 100-gram Rock to Fall 100 Meters on Different Celestial Bodies

Body	Mass of the Body (kg)	Time it takes the same rock to impact the surface from 100 meters away
Earth	$5.98 * 10^{24}$	4.51 seconds
Mercury	$3.30 * 10^{23}$	7.35 seconds
Venus	$4.87 * 10^{24}$	4.72 seconds
Mars	$6.42 * 10^{23}$	7.33 seconds
Jupiter	$1.90 * 10^{27}$	0.90 seconds
Saturn	$5.69 * 10^{26}$	1.38 seconds
Uranus	$8.68 * 10^{25}$	2.04 seconds
Neptune	$1.02 * 10^{26}$	1.97 seconds
Pluto	$1.29 * 10^{22}$	17.53 seconds
Moon	$7.35 * 10^{22}$	11.10 seconds
Sun	$1.99 * 10^{30}$	0.42 seconds

Resource Card 3: Computer Simulation Model

The reason why everything on Earth falls downwards is because of gravity. And yet, we saw in other resources that gravity does not just mean "falls towards Earth." Gravity attracts objects to other large bodies and on those bodies objects can fall at different rates. Let's explore this more in this simulation of our solar system.

Instructions:
Open the pHet simulation on **Gravity and Orbits**.

Part 1:

1. Click the selection showing the Sun and the Earth.

2. Click the boxes to show Gravity Force and Path.
    a. Note: Gravity Force is shown with an arrow. The bigger the arrow, the bigger the force.

3. Play around with the mass of the sun, increasing and decreasing it.

4. Analyze and discuss your observations with your group members and use it to answer the questions in your student guide.

Part 2:
Reset All on your simulation. Then,

1. Click the selection showing the Earth and Moon.

2. Click the box to show Gravity Force.

3. Play around with the mass of the moon, increasing and decreasing it.

4. Play around with the mass of the Earth, increasing and decreasing it.

5. Analyze and discuss your observations with your group members and use it to answer the questions in your student guide.