Integrated STEM Unit Planner

Grade 4 Science

Safeguard a Vehicle

Share your success and questions: prek12stem.com

PreK-12STEM

Community Training & Assistance Center (CTAC)

Tracy Unified School District

About the Integrated STEM Units

The integrated STEM units are a product of the partnership between Community Training and Assistance Center (CTAC) and Tracy Unified School District (TUSD) in California, funded in part through the Education Innovation and Research (EIR) program of the U.S. Department of Education in 2018. Teacher leaders came together to develop innovative units that align to STEM standards for student learning—namely the Next Generation Science Standards (NGSS) for California Public Schools, the Computer Science Content Standards derived from the national K-12 Computer Science Framework, and the California Common Core State Standards.

Each integrated unit brings together the following:

- an engineering design challenge
- one or more computational artifacts
- core science and math content
- language building opportunities
- engagement supports

Students in each grade level, pre-kindergarten through twelve, engage with the unit for about one or two months as part of their required coursework. The units are integrated and self-contained as a means to provide all students with equitable STEM experiences.

About the Partners

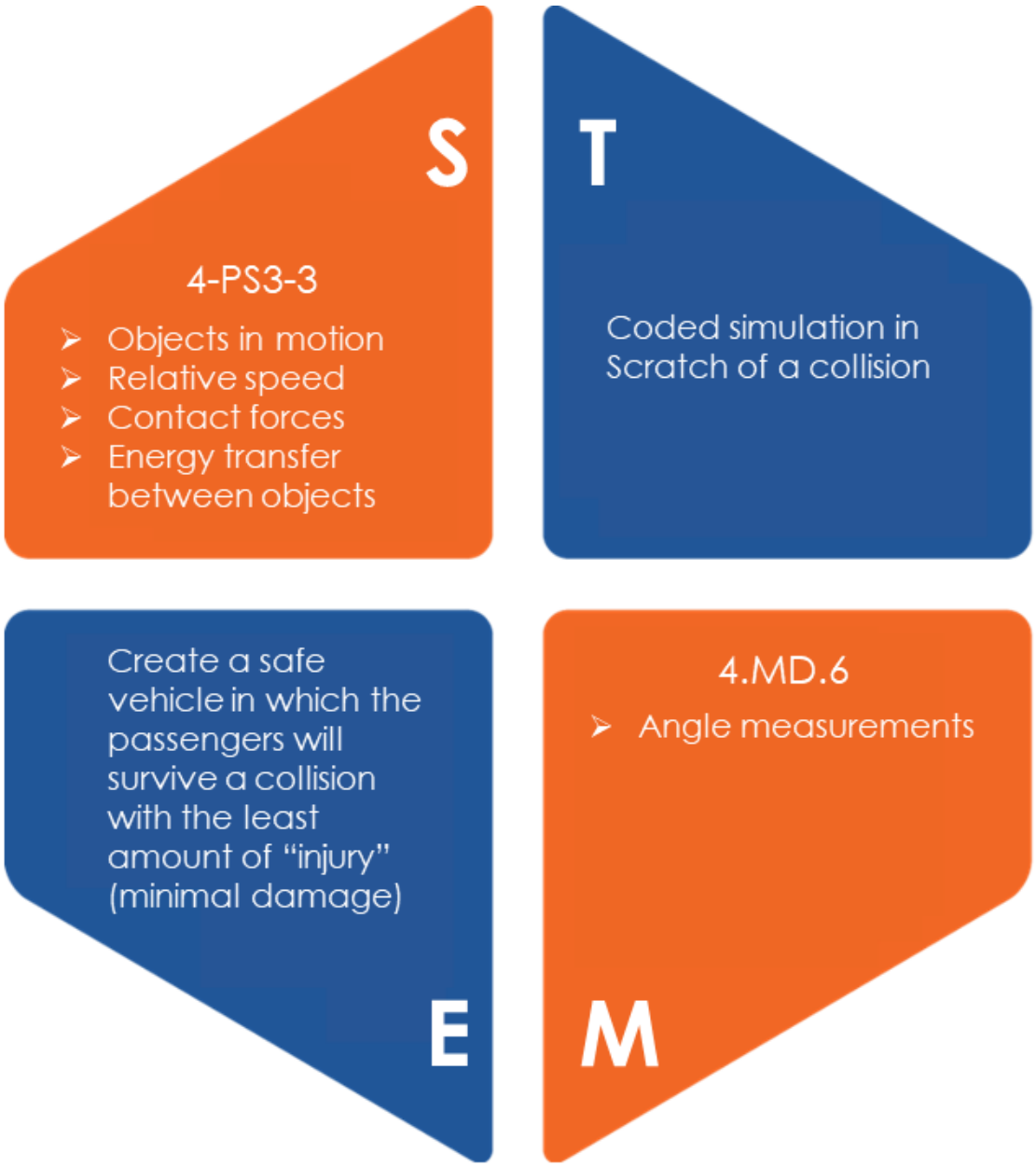
Community Training and Assistance Center (CTAC) is a national not-for-profit organization with a demonstrated record of success in the fields of education and community development. Tracy Unified School District, located in California's Central Valley, serves approximately 15,000 students. Fifty leading teachers from the district contributed to the development of the units. Computer Science integrations resulted with support from the San Joaquin County Office of Education and Bootstrap of Brown University.

Terms of Use

Contents

Big Picture

Unit Emblem



Focal Standard

4-PS3-3 Ask questions and predict outcomes about the changes in energy that occur when objects collide. [Clarification Statement: Emphasis is on the change in the energy due to the change in speed, not on the forces, as objects interact.] [Assessment Boundary: Assessment does not include quantitative measurements of energy.]

Overview

Sequence 1: Teachers engage students with an anchoring phenomenon by use the simulation at seen at PhET Interactive Simulations.[i] The simulation on collisions (https://bit.ly/3A8T6yj allows the user to alter the mass and velocity of objects in collisions. Students will be able to make predictions about the effect of changes in the parameters on the outcomes of collisions.

Students will begin to ***ask*** questions about the transfer of energy from one object to another, how the size of the object affects its motion in a collision, how objects move in a collision and why damage occurs when objects collide. Student will be presented with the design challenge to construct a vehicle and test its safety by rolling it down a ramp and using an egg as its passenger. The survival of the egg will demonstrate the safety of the vehicle.

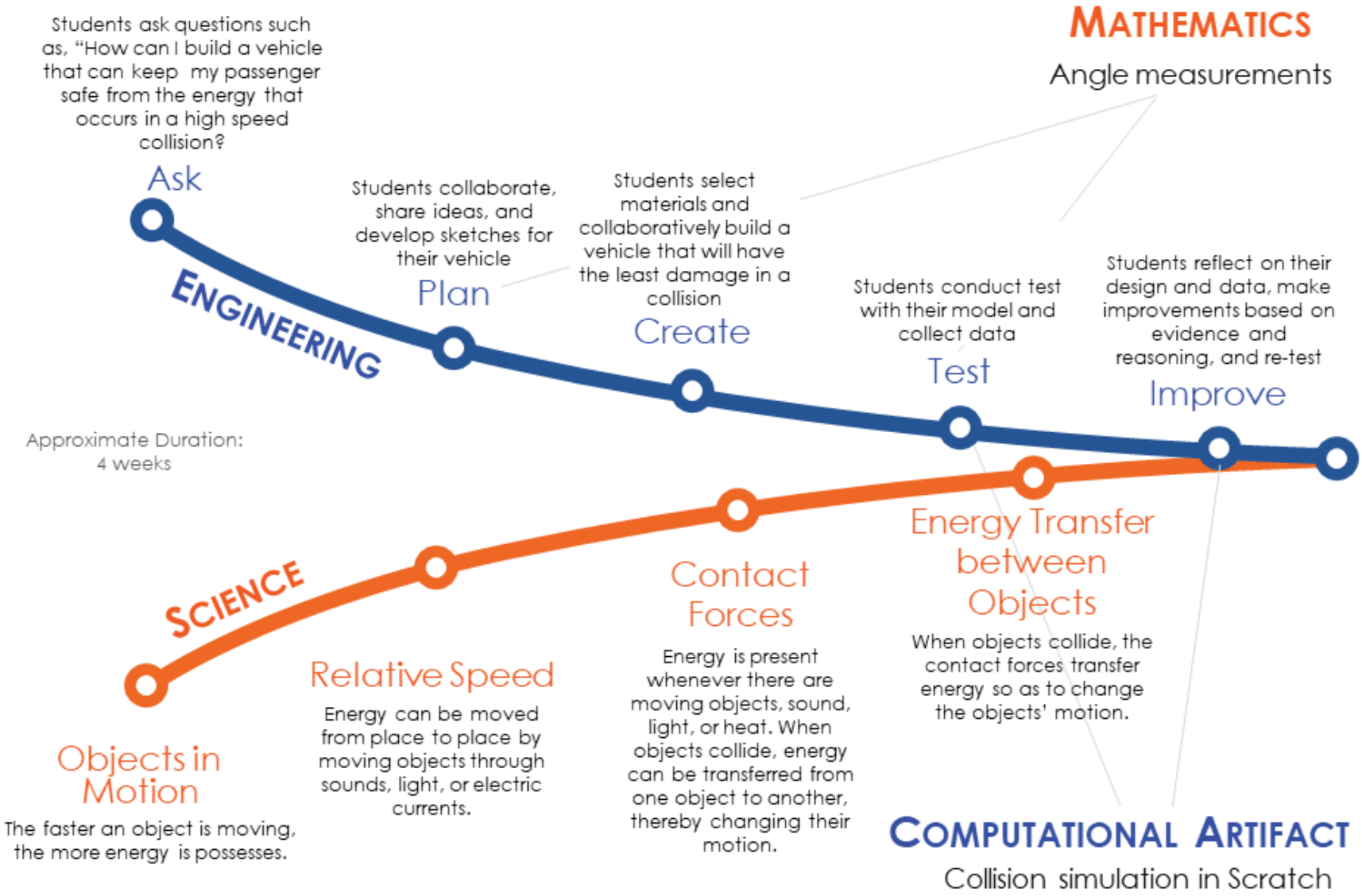
Sequence 2: Students learn about the impact of energy and speed on the motion of an object and how speed affects collisions. They will begin to ***plan*** their vehicle based on this learning and considering the materials available to them

Sequence 3: Students will ***create*** their vehicles considering learning about what happens to energy when objects in motion collide.

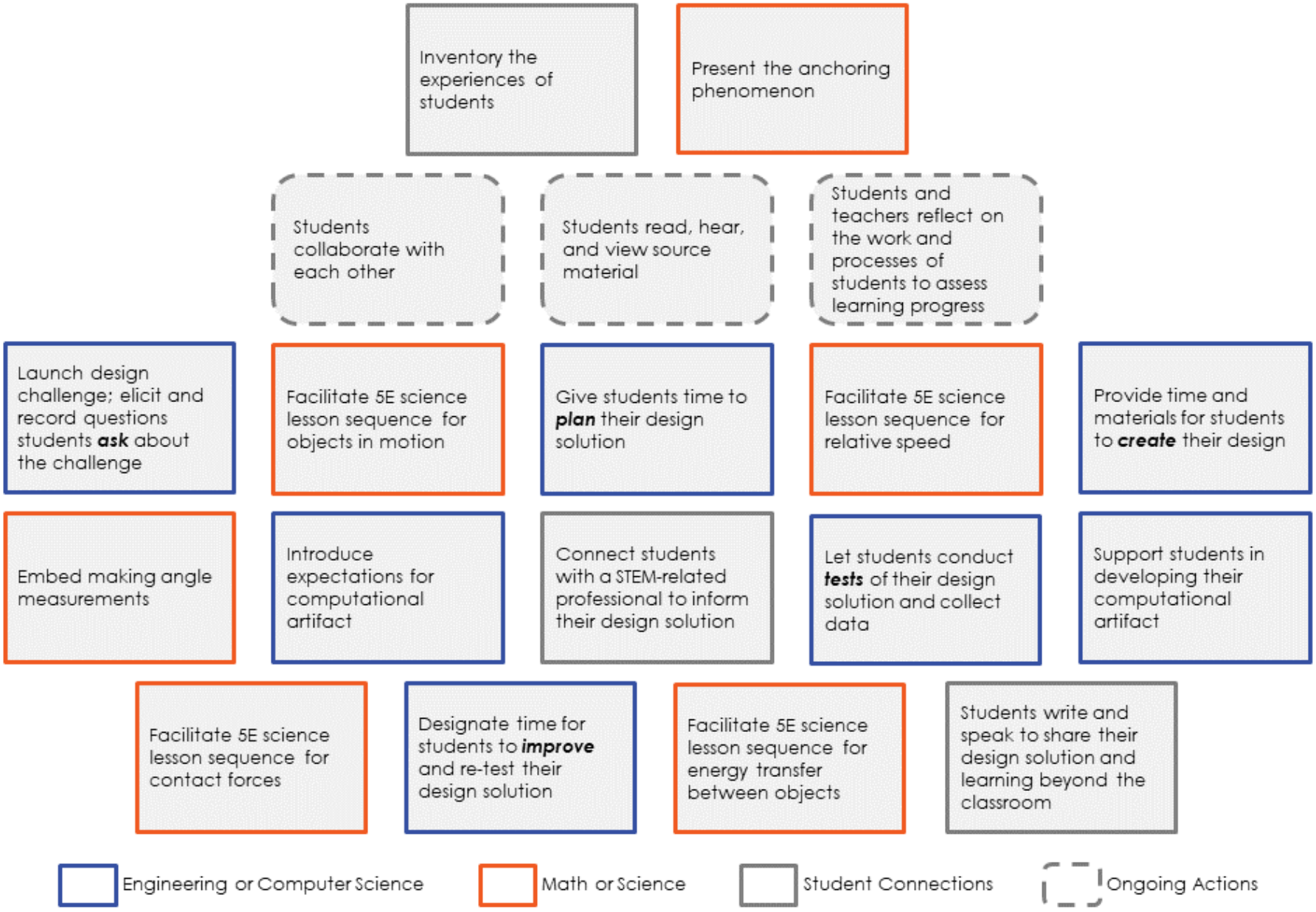
Sequence 4: Students then begin to ***test*** their prototype, collecting data whether their egg survives. They will use their learning about ways to test predictions about collisions and improve their predictions over time.

Sequence 5: Students reflect on their data and revise the plan to ***improve*** their model and then conduct follow-up tests on their improved vehicle. Students will create a coding simulation to demonstrate the outcome of energy transfer related to the speed of objects in collisions.

Integrated Unit Storyline



Integrated Unit Wayfinder



STEM Dive

Engineering

Design Challenge: Create a safe vehicle in which passengers will survive with the least amount of "injury" (minimal damage)

Type of Engineering: Automotive Engineering

The Engineering Design Process (EDP) and Engineering Standards

EDP Step	Standard and Grade Band End Points from the *Framework*
Ask *How can I build a vehicle that can keep my passenger safe from the energy that occurs in a high speed collision?*	**3-5-ETS1-1.** 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. • 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. (3-5-ETS1-1)
Plan *Students collaborate, share ideas, and develop sketches for their vehicle*	**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. • 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. (3-5-ETS1-2) • 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. (3-5-ETS1-2)
Create *Students select materials and collaboratively build a vehicle that will have the least damage in a collision*	
Test *Students conduct tests with their model and collect data*	**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. • Tests are often designed to identify failure points or difficulties, which suggest the elements of the design that need to be improved. (3-5-ETS1-3) • Different solutions need to be tested in order to determine which of them best solves the problem, given the criteria and the constraints. (3-5-ETS1-3)
Improve *Students reflect on their design and data, make improvements based on evidence and reasoning, and re-test*	

Computer Science (Technology)

Computer Science Integrations

Description of Student Engagement

Students will code a simulation in Scratch to demonstrate the outcome of energy transfer related to the speed of objects in collisions.

Computational Artifact

Definition: Anything created by a human using a computational thinking process and a computing device. A computational artifact can be, but is not limited to, a program, image, audio, video, presentation, or web page file. (Source: College Board, 2016)

- Coding and simulation in Scratch

Hardware

Definition: The physical components that make up a computing system, computer, or computing device. (Source: MDESE, 2016)

- Computer

Software (includes programs, applications, websites, etc.)

Definition: Programs that run on a computing system, computer, or other computing device. (Source: k12cs.org)

- Scratch

Standards

- **3-5.DA.8** Organize and present collected data visually to highlight relationships and support a claim.
- **3-5.AP.11** Create programs that use variables to store and modify data.
- **3-5.AP.13** Decompose problems into smaller, manageable tasks which may themselves be decomposed.

Science

Focal Standard

4-PS3-3 Ask questions and predict outcomes about the changes in energy that occur when objects collide. [Clarification Statement: Emphasis is on the change in the energy due to the change in speed, not on the forces, as objects interact.] [*Assessment Boundary: Assessment does not include quantitative measurements of energy*.]

Related Content Standards

4-PS3-1 Use evidence to construct an explanation relating the speed of an object to the energy of that object. [*Assessment Boundary: Assessment does not include quantitative measures of changes in the speed of an object or on any precise or quantitative definition of energy*.]

Anchoring Phenomenon

Teachers engage students with a PhET simulation,[ii] making predictions about various collisions and changing variables. Website: https://phet.colorado.edu/en/simulations/collision-lab

Content Outline

Below is a content outline for the science content in this unit. It includes the key concepts within the unit along with an approximate number of days it would take to facilitate a sufficient amount of student learning experiences. For each key concept, key learnings appear, which come from the grade band endpoints in *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (source: https://www.nextgenscience.org/framework-k-12-science-education). The storyline begins with an anchoring phenomenon.

Key Concept	Key Learnings	# of Days
Objects in Motion	• The faster a given object is moving, the more energy it possesses. (4-PS3-1)	
Relative Speed	• Energy can be moved from place to place by moving objects or through sound, light, or electric currents. (4-PS3-3)	
Contact Forces	• Energy is present whenever there are moving objects, sound, light, or heat. When objects collide, energy can be transferred from one object to another, thereby changing their motion. In such collisions, some energy is typically also transferred to the surrounding air; as a result, the air gets heated and sound is produced. (4-PS3-3)	

Key Concept	Key Learnings	# of Days
Energy Transfer between Objects	• When objects collide, the contact forces transfer energy so as to change the objects' motions. (4-PS3-3)	

Science and Engineering Practices	Crosscutting Concepts
1. Asking questions and defining problems 2. Developing and using models **3. Planning and carrying out investigations** 4. Analyzing and interpreting data 5. Using mathematics and computational thinking **6. Constructing explanations and designing solutions** **7. Engaging in argument from evidence** 8. Obtaining, evaluating, and communicating information	1. Patterns **2. Cause and effect** 3. Scale, proportion, and quantity **4. Systems and system models** **5. Energy and matter** 6. Structure and function 7. Stability and change

Note. Bolded items are called out specifically in the standards cluster for this unit.

Mathematics

Description of Student Engagement

Students measure angles of the vehicle trial ramp to alter the speed of the vehicle and measure the impact.

Standards for Mathematical Content

4..MD.6 Measure angles in whole-number degrees using a protractor. Sketch angles of specified measure.

Standards for Mathematical Practice

MP.1 Make sense of problems and persevere in solving them.

MP.2 Reason abstractly and quantitatively.

MP.3 Construct viable arguments and critique the reasoning of others.

MP.4 Model with mathematics.

MP.5 Use appropriate tools strategically.

MP.6 Attend to precision.

MP.7 Look for and make use of structure.

MP.8 Look for and express regularity in repeated reasoning.

Note. Bolded items are emphasized in this unit.

English Language Arts and Development

Reading Standard: Key Idea and Details

RI.4.2 Determine the main idea of a text and explain how it is supported by key details; summarize the text clearly.

Reading Standard: Integration of Knowledge and Ideas

RI.4.7 Interpret information presented visually, orally, or quantitatively (e.g., in charts, graphs, diagrams, timelines, animations, or interactive elements on Web pages) and explain how the information contributes to an understanding of the text in which it appears.

Writing Standard: Text Types and Purposes

W.4.3 Write narratives to develop real or imagined experiences or events using effective technique, descriptive details, and clear event sequences.

Writing Standard: Research to Build and Present Knowledge

W.4.7 Conduct short research projects that build knowledge through investigation of different aspects of a topic.

W.4.8 Recall relevant information from experiences or gather relevant information from print and digital sources; take notes, categorize information, and provide a list of sources.

Speaking and Listening Standard: Comprehension and Collaboration

SL.4.1 Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 4 topics and texts, building on others' ideas and expressing their own clearly.

Speaking and Listening Standard: Presentation of Knowledge and Ideas

SL.4.4 Report on a topic or text, tell a story, or recount an experience in an organized manner, using appropriate facts and relevant, descriptive details to support main ideas or themes; speak clearly at an understandable pace.

SL.4.5 Add audio recordings and visual displays to presentations when appropriate to enhance the development of main ideas or themes.

Language: Knowledge of Language

L.4.3 Use knowledge of language and its conventions when writing, speaking, reading, or listening.

- **L.4.3.c** Differentiate between contexts that call for formal English (e.g., presenting ideas) and situations where informal discourse is appropriate (e.g., small-group discussion).

Unit Vocabulary

The following terms reflect the core vocabulary students should understand and use in this unit.

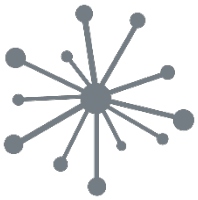
- **absorb**: To absorb is to take in (something, such as water) in a natural or gradual way. (Source: https://www.merriam-webster.com/dictionary/absorb)
- **acceleration**: Acceleration is the act or process of speeding up. (Source: https://www.merriam-webster.com/dictionary/acceleration)
- **collide**: To collide is to hit something or each other with strong force : to crash together or to crash into something. (Source: https://www.merriam-webster.com/dictionary/collide)
- **collision**: A collision is an accident that happens when two vehicles hit each other with force. (Source: https://dictionary.cambridge.org/us/dictionary/english/collision)
- **conversion**: Conversion is the process of converting something from one thing to another. (Source: https://dictionary.cambridge.org/us/dictionary/english/conversion)
- **electricity**: Electricity is an important form of energy that is found in nature but that can be artificially produced by rubbing together two unlike things (as glass and silk), by the action of chemicals, or by means of a generator. (Source: https://www.merriam-webster.com/dictionary/electricity)
- **energy**: Energy is usable power or the resources (as oil) used to produce usable power. (Source: https://www.merriam-webster.com/dictionary/energy)
- **gravity**: Gravity is the force by which a planet or other body draws objects toward its center. The force of gravity keeps all of the planets in orbit around the sun. (Sourced from NASA: https://go.nasa.gov/3hmQUM8)
- **heat**: Heat is a form of energy that can be transferred from one place or object to another when there is a difference in temperature. (Sources from NASA: https://go.nasa.gov/38Ntb33)
- **motion**: Motion is an act, process, or instance of changing place. (Source: https://www.merriam-webster.com/dictionary/motion)
- **sound energy**: Sound is the movement of energy through substances in longitudinal (compression/rarefaction) waves. Sound is produced when a force causes an object or substance to vibrate. The energy is transferred through the substance in a wave. Typically, the energy in sound is smaller than in other forms of energy. (Sourced from U.S. Energy Information Administration: https://bit.ly/3jMYnpn

- **speed**: Speed is rate of moving or doing [something]. (Source: https://www.merriam-webster.com/dictionary/speed)

- **transform (change)**: To transform is to change in composition or structure. (Source: https://www.merriam-webster.com/dictionary/transform)

- **velocity**: Velocity is the quickness of motion. (Source: https://www.merriam-webster.com/dictionary/velocity)

Assessment Tools



Student Experience Inventory

Teachers can use the following prompts with students prior to the beginning of the unit or early in the unit in order to learn about students' experiences that relate to the unit. Teachers can make informed instructional decisions based on this learning, enabling tailored opportunities for students to make their own meaning.

Student Prompts

1. What objects do you see moving by you on a normal day? Which objects would you say move fast and which would you say move slowly?

2. Describe a time you saw two objects hit each other. What happened before and after they hit?

3. When you're riding and the car stops then starts again, what do you notice about things inside the car that move?

Aligned Learnings

1. Responses to this item provide insight into students' experiences of moving objects and their relative speed. 4-PS3-1

2. Responses to this item provide insight into students' experiences with collisions. 4-PS3-3

3. Responses to this item provide insight into students' experiences with vehicle motion and the effects of slowing down and speeding up. 4-PS3-1

Student Self-Assessment of Engineering

Improve:
Here is what would make my design better and why…

Ask:
Here is what I am wondering about before I plan my design…

Plan:
Here are my design ideas for the project…

Test:
Here are the data I collected…

Create:
Here is what I think about what I made compared to what I planned, and here is what I think will happen when I test it…

I am doing the work of a automotive engineer.

One-Point Design Challenge Rubric

Criteria serve as a primary reference point throughout the engineering design process. Teachers use the criteria **to communicate expectations** and **to guide students**. With teacher guidance, students use the criteria to inform and reflect on their work.

Approaches Expectations *Notes on how to improve the project*	**Meets Expectations** *Criteria indicating success*	**Exceeds Expectations** *Notes on how project goes beyond expectations*
	Engineering Students participate in the 5-part engineering design process, use data, and make thoughtful improvements to their design. (3-5-ETS1-1, 3-5-ETS1-2, 3-5-ETS1-3)	
	Computer Science The computational artifact shows success coding to simulate the transfer of energy in a collision. (3-5.DA.8, 3-5.AP.11, 3-5.AP.13)	
	Collaboration Students give and receive input with kindness and honesty. (SL.4.1.a-d, 4.4, SL.4.5)	
	Communication Students speak and write about their ideas clearly using accurate vocabulary (W.4.2, W.4.7). I can share thoughts, read, and listen to learn from others. (SL4.4, SL.4.5))	
	Science Students design a vehicle and explain how energy transfers in a collision in relation to its speed. (4-PS3-1 4-PS3-1)	

Engagement

Community and Career Connections

During the unit, students engage with STEM professionals who can inform students' work at some point during the engineering design process. The interaction with STEM professionals serves a few purposes:

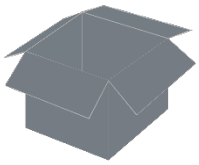
- Expose students to STEM as it applies in various careers
- Enrich student learning through collaborating with STEM professionals
- Help students see themselves doing the actual work of STEM

Below are a few potential STEM-related professionals that align to one of California's 15 industry sectors for Career and Technical Education:

- **Computer Simulation Developer** (Engineering and Architecture)
- **Crash Scene Investigator from Police Department** (Public Services)
- **Race Car Driver** (Altamont Race Track) (Hospitality, Tourism and Recreation)

The interactive experience will ideally be co-constructed by the teacher and professional. In coordinating with the professional, a few questions appear below that can be used to guide the planning and live interaction with students:

- **Computer Simulation Developer** (Engineering and Architecture)
  - What kind of computer simulations do you create?
  - Why are these simulations developed (e.g., for gaming, part of "how-to" support materials, learning tools for students, etc.)?
  - How did you learn how to do this job? When you were a student, what kinds of things did you do that helped you build the skills you need for this job?
  - What kind of problems do you encounter in simulations? Can you get a "bug" in your programming? How do you solve those problems?
- **Crash Scene Investigator from Police Department** (Public Services)
  - When you arrive at the scene of the crash what is the first thing you do?
  - What kinds of measurements do you take? Can you tell the speed of a car from the length of the skid marks or something else on the scene?
  - What other kinds of clues do you look for when trying to explain a crash?
  - What tools does a Crash Scene Investigator use?
- **Race Car Driver** (Altamont Race Track) (Hospitality, Tourism and Recreation)
  - What is built into a race car to help you survive crashes safely?
  - Are there any parts of the safety equipment that interfere with your ability to drive the car?
  - Do you think there should be more protective equipment in the cars? What would you suggest?
  - What types of cars do you drive and how are they different from a car on the road?
  - What is one problem you face in your day-to-day work?



Materials List

The items in the materials list below reflect total quantities for a class of 32 students, allowing for 8 groups of 4 students.

Permanent Equipment (classroom totals):

- ☐ 32 cardboard ramps (4 from each tri-fold presentation board)
- ☐ 124 wheels
- ☐ 62 axles

Consumable Equipment (classroom totals):

- ☐ 3 dozen eggs
- ☐ 320 (3 oz.) paper cups
- ☐ 124 sheets of cardstock
- ☐ 320 cotton balls
- ☐ 32 rolls of clear tape
- ☐ 160 rubber bands
- ☐ 192 pipe cleaners
- ☐ 160 craft sticks

Distance Learning Modifications

In distance learning, the design challenge will be conducted by students individually at home. Student collaboration will need to occur remotely with a modified materials list.

Modified Materials List (student totals):

- ☐ 1 cardboard ramp (1/4 of a trifold)
- ☐ 4 wheels
- ☐ 2 axles
- ☐ 3 eggs
- ☐ 10 paper cups
- ☐ 4 sheets of cardstock
- ☐ 1 handful (about 10) cotton balls
- ☐ 1 roll of clear tape
- ☐ 5 rubber bands
- ☐ 6 pipe cleaners
- ☐ 5 craft sticks

Endnotes

[i] PhET Interactive Simulations (2022). University of Colorado Boulder. *Simulations: Physics.* https://phet.colorado.edu/en/simulations/filter?subjects=physics&type=html,prototype

[ii] PhET Interactive Simulations. (2022). *Collision Lab (Version 1.1.5)*. University of Colorado Boulder. https://phet.colorado.edu/en/simulations/collision-lab