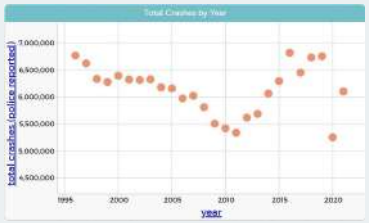
Lesson 1: Why is driving safer today than it was ten years ago, even though the number of vehicle collisions has gone up?

Previous Lesson *There is no previous lesson.*

This Lesson

Anchoring Phenomenon

4 days



Images generated using CODAP (https://codap.concord.org/), developed at the Concord Consortium; Data Source: NHSTA

We analyze graphs of vehicle deaths and injuries over time and determine that while deaths have decreased overall, we see a slight increase in injuries and vehicle collisions in recent years. We develop models to predict how distracted driving and vehicle factors and features might contribute to these trends. We ask questions about potential causes for trends we observed and develop ideas for investigations to help figure out the answers to our questions.

Next Lesson *We will analyze videos of two drivers encountering a sudden obstacle: one who is undistracted and one who is distracted.*

BUILDING TOWARD NGSS

HS-ETS1-3, HS-PS2-2, HS-PS2-3, HS-PS2-1

What students will do

1.A Ask questions about patterns in vehicle safety over time that we have identified using empirical data and about factors that might have affected them (such as driver distraction, safety features, vehicle mass, and vehicle velocity). (SEP: 1.1; CCC: 1.5; DCI: PS2.A, ETS1.A.2)

1.B Develop a model of a vehicle-driver system that includes safety components designed to alter the physics of a collision in order to predict the impact of these components on traffic safety statistics. (SEP: 2.6; CCC: 2.3; DCI: PS2.A, ETS1.A.2)

What students will figure out

- While overall trends in deaths have decreased, in recent years the number of collisions and injuries has increased.
- There are many potential causes for these trends, including changes in driver behavior (such as distracted driving), changes to vehicle design (such as airbags), changes to road conditions (such as stop signs that are easier to see), and changes to policy (such as speed limits).

Lesson 1 • Learning Plan Snapshot

Part	Duration		Summary	Slide	Materials
1	5 min		**EXPLORE A NEW PHENOMENON** Introduce a new phenomenon about vehicle fatalities and elicit initial ideas about what makes driving risky, what can make driving safer, and whose safety we are taking into account. Be aware of supporting students' social and emotional well-being using the accompanying teacher reference, student handout, callouts, and home letter.	A-C	*Student Mindfulness Resource*, *Pre-Unit Letter Home*, Community Agreements
2	10 min		**MAKE PREDICTIONS AND TEST THEM** Have students make predictions about whether driving has gotten more safe or less safe over time, why, and for whom. Poll their predictions and solicit ideas. Observe a graph of crashes over time and make a record of trends the class noticed.	D-E	1 sheet loose-leaf paper, *Total Crashes Over Time (since 1996)*, chart paper, chart paper markers
3	15 min		**ANALYZE DATA AND MAKE CONNECTIONS** Consider how to quantify safety and then break into small groups to analyze data sets that help students quantify safety in various ways. Look for patterns in groups that might be related to the trends they noticed in crashes over time.	F-G	1 Data Jigsaw handout (either *Data Jigsaw A: Vehicle Miles Traveled* or *Data Jigsaw B: US Traffic Fatalities* or *Data Jigsaw C: Percent of Traffic Crashes with Fatalities and Injuries* or *Data Jigsaw D: Non-occupants Killed in Traffic Crashes* or *Data Jigsaw E: Registered Vehicles* or *Data Jigsaw F: Percent of Fatalities that Were Alcohol-Related*), whiteboard, dry erase markers (multiple colors)
4	15 min		**KEEP TRACK OF PUZZLING PATTERNS IN A SCIENTISTS CIRCLE** Share major patterns that groups noticed in the data. Record these on chart paper as a public record of "Puzzling Patterns" that students would like to be able to explain.	H-I	chart paper, chart paper markers
					End of day 1
5	3 min		**NAVIGATE: TURN AND TALK ABOUT PUZZLING PATTERNS** Turn and talk in a Scientists Circle about the Puzzling Patterns identified last time.	J	Puzzling Patterns poster

6	18 min	**BUILD UNDERSTANDINGS ACROSS DATA SETS IN THE SCIENTISTS CIRCLE** Lead a Building Understandings Discussion about change across data sets. Notice and wonder about a timeline of vehicle safety. Make a public record of design solutions and other factors that we think might be important.	K-M	*Timeline of Vehicle Safety*, What can affect the outcome of a collision? poster, chart paper markers, Puzzling Patterns poster
7	9 min	**MODEL COLLISIONS WITH TOY CARS** Use toy cars in groups to model collision scenarios and consider what new ideas this raises about the two-car system. Add to the What can affect the outcome of a collision? poster.	N	1 small toy car, 1 larger toy car, What can affect the outcome of a collision? poster, chart paper markers
8	15 min	**DEVELOP INITIAL MODELS** Develop individual models to explain how and why various design solutions or other factors might impact outcomes before and during a vehicle collision. Work in small groups to combine ideas and create a group model.	O-Q	*Initial Model*, 1 sheet chart paper, chart paper markers (assorted colors)

End of day 2

9	20 min	**GALLERY WALK PASS 1: COMPARE INITIAL MODELS** Do a gallery walk to compare initial models. As a class, debrief and consider how energy, matter, and forces show up (or not) in the models.	R-S	group model posters, M-E-F triangle poster (from *Earth's Interior Unit*)
10	10 min	**GALLERY WALK PASS 2: LOOK FOR M-E-F** Do a second pass on the gallery walk with a partner, focusing on M-E-F ideas. Use color-coded sticky notes to make a record of where these ideas might be important.	T	5 3x3 sticky notes (pink), 5 3x3 sticky notes (green), 5 3x3 sticky notes (purple), M-E-F triangle poster (from *Earth's Interior Unit*)
11	15 min	**DEVELOP AN INITIAL CONSENSUS MODEL** Lead a Consensus Discussion to develop an initial model.	U	Initial Consensus Model poster, chart paper markers (assorted colors)

End of day 3

12	5 min	**NAVIGATE: TURN AND TALK ABOUT THE INITIAL CONSENSUS MODEL** Turn and talk about the Initial Consensus Model to reveal gaps in what we can explain right now.	V	Initial Consensus Model poster
13	7 min	**DEVELOP QUESTIONS FOR THE DRIVING QUESTION BOARD**	W-X	2-3 3x3 sticky notes, permanent marker, pencil

		Get students thinking about gaps in what they know by leading a discussion about what they need to know to advocate for solutions in their community. Then develop questions for the DQB.		
14	17 min	**BUILD THE DRIVING QUESTION BOARD** Support students in building the DQB. Name the DQB and the major clusters. Create a new poster with cluster titles that will become the Ideas for Future Investigations and Data We Need poster.	Y-Z	DQB questions on 3x3 sticky notes, chart paper, chart paper markers, Initial Consensus Model poster, Community Agreements
15	16 min	**IDENTIFY RELATED PHENOMENA AND IDEAS FOR INVESTIGATIONS** Consider other phenomena besides vehicle collisions that could be explained by answering our questions. Record ideas for investigations and data needed on sticky notes for the relevant topic cluster.	AA-BB	2-3 3x3 sticky notes, Ideas for Future Investigations and Data We Need poster, chart paper markers, Related Phenomena poster

End of day 4

Lesson 1 • Materials List

	per student	per group	per class
Lesson materials	• *Student Mindfulness Resource* • *Pre-Unit Letter Home* • 1 sheet loose-leaf paper • science notebook • *Total Crashes Over Time (since 1996)* • 1 Data Jigsaw handout (either *Data Jigsaw A: Vehicle Miles Traveled* or *Data Jigsaw B: US Traffic Fatalities* or *Data Jigsaw C: Percent of Traffic Crashes with Fatalities and Injuries* or *Data Jigsaw D: Non-occupants Killed in Traffic Crashes* or *Data Jigsaw E: Registered Vehicles* or *Data Jigsaw F: Percent of Fatalities that Were Alcohol-Related*) • *Timeline of Vehicle Safety* • *Initial Model* • 5 3x3 sticky notes (pink) • 5 3x3 sticky notes (green) • 5 3x3 sticky notes (purple) • 2-3 3x3 sticky notes • permanent marker • pencil • DQB questions on 3x3 sticky notes	• whiteboard • dry erase markers (multiple colors) • 1 small toy car • 1 larger toy car • 1 sheet chart paper • chart paper markers (assorted colors)	• Community Agreements • chart paper • chart paper markers • Puzzling Patterns poster • What can affect the outcome of a collision? poster • group model posters • M-E-F triangle poster (from *Earth's Interior Unit*) • Initial Consensus Model poster • chart paper markers (assorted colors) • Ideas for Future Investigations and Data We Need poster • Related Phenomena poster

Materials preparation (30 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Make copies of the handouts for this lesson:

- *Total Crashes Over Time (since 1996)* (1 per student)
- *Data Jigsaw A: Vehicle Miles Traveled* (1 per jigsaw group)
- *Data Jigsaw B: US Traffic Fatalities* (1 per jigsaw group)
- *Data Jigsaw C: Percent of Traffic Crashes with Fatalities and Injuries* (1 per jigsaw group)
- *Data Jigsaw D: Non-occupants Killed in Traffic Crashes* (1 per jigsaw group)
- *Data Jigsaw E: Registered Vehicles* (1 per jigsaw group)
- *Data Jigsaw F: Percent of Fatalities that Were Alcohol-Related* (1 per jigsaw group)
- *Student Mindfulness Resource* (1 per student)
- *Modeling with Toy Cars* (1 per student)
- *Timeline of Vehicle Safety* (1 per student)
- *Initial Model* (1 per student)

Put three-hole-punches in all the images and handouts so they can be added to students' notebooks.

Make sure the M-E-F triangle poster (developed in *Earth's Interior Unit*) is displayed near the front of the room.

Prepare chart paper for posters. The posters you will develop in this lesson include:

- Puzzling Patterns
- What can affect the outcome of a collision?
- Initial Consensus Model
- Driving Question Board (DQB)
- Related Phenomena
- Ideas for Investigations and Data We Need

It can be helpful to title these posters ahead of time so they can be revealed during the lesson more quickly. Be ready to save all of these posters for each section, as you will need these in future lessons.

To prepare the poster titled "What can affect the outcome of a collision?", sketch a T-chart as shown in **slide M**. Label the left side "Design Solutions" and the right side "Other Factors".

Before beginning this unit, consider the nature of the content in your classroom context. This lesson addresses statistics on car crashes and fatalities, which may evoke trauma for students, teachers, and families. In later lessons, students will be asked to work with data from individual collisions to solve physics problems. Please see the unit front matter, the teacher reference (*Trauma-Informed SEL Supports*) associated with this lesson, the *Student Mindfulness Resource*, and the callouts in the *Teacher Guide* for guidance around how to support social and emotional needs as you move through this unit. **Refrain from asking students to share their personal experiences unless they volunteer to do so.**

Before beginning this unit, make sure to reach out to a counselor or a mental health professional at your school for student-specific support and strategies that might be needed in regard to the students in your classroom, and consider asking a counselor to join you on the first day of instruction. Also consider planning follow-up check-ins with the counselor regarding any students who may need additional emotional support.

At the front of the slideshow bundled with this lesson is a teacher-facing slide meant to alert you to sensitive content. When you see this slide in subsequent lessons, know that the lesson deals with the physics of crashes and fatalities and that some students may require additional support.

After this slide is a student-facing slide titled "Student Content Advisory". **Note that this slide is designed to be shown to students in advance of Lesson 1.** We recommend showing this slide to students on the same day that you send out the letter home to students' caregivers, at least a week ahead of the first lesson. This way students and caregivers have a chance to contact you, and you can connect them to resources ahead of time.

Reach out to students' support system at home before the unit, using *Pre-Unit Letter Home*. This letter is a way to communicate with trusted adults and make them aware of the content of the unit. The letter also provides an opportunity for trusted adults to share important context with you about students' experiences and background that might be relevant.

Be aware that students who are struggling may demonstrate a variety of behaviors, including but not limited to fidgeting, withdrawal, disruption or distraction, rapid breathing, holding their breath, or change in body language or tonation. If you notice that a student might be struggling, share what you are observing and ask whether they need some help.

Consider customizing the mental health resources list available to students on *Student Mindfulness Resource* to refer to specific people and/or resources available at your school or in your community.

Lesson 1 • Where We Are Going and NOT Going

Where We Are Going

In this lesson, students analyze data on motor vehicle collisions, injuries, and deaths over time and identify trends in the data. They consider some of the potential causes for the trends and develop questions that require empirical evidence to answer. They begin to think about how the design of a vehicle might impact the outcome of a collision and what can be done to improve those outcomes. They also begin to consider the impact of being distracted on the probability of being in a collision.

Students will have ideas about vehicle collisions, distracted driving, and so forth. Some may bring in ideas about forces and momentum. Accept all of these ideas without judgment right now, even if they are scientifically inaccurate. If a student puts an idea on the table that feels very inaccurate, you can respond with one of the following:

- *Wow, that's an interesting idea! Does anybody disagree?*
- *Let's follow up on that, for sure. How could we investigate the claim _____ made? Let's add that to our ideas for investigations later.*
- *What an interesting idea. Could you reframe that as a question for our Driving Question Board?*

In Lesson 1 and throughout this unit, students are encouraged to consider how humans and nonhumans outside a vehicle might be impacted by decision making related to vehicle safety. Encourage students to think about the safety not only of the driver and passengers but also of pedestrians, trees, and animals. They might also think more broadly about safety--for example, considering the impact of larger vehicles on emissions--and the resulting impact on the natural world.

This lesson draws on some of the ideas about engineering developed in the first unit of the OpenSciEd HS Physics course (*Electricity Unit*) by introducing another major global challenge with manifestations in students' communities: vehicle safety. The following DCI element, which is also covered in the *Electricity Unit*, is therefore reinforced in this lesson:

ETS1.A: Defining and Delimiting Engineering Problems

- Humanity faces major global challenges today~~, such as the need for supplies of clean water and food or for energy sources that minimize pollution~~, which can be addressed through engineering. These global challenges also may have manifestations in local communities. (HS-ETS1-1)

Because this is the first lesson in a new unit, the goal is not to establish any science ideas, but rather to get student ideas on the table. This lesson is an opportunity to pre-assess students' ideas about how force, mass, and velocity might affect changes in motion in a system. Thus, even though students will not develop ideas related to Newton's second law until Lessons 4-8 of this unit, this lesson was designed to **elicit ideas** related to the following disciplinary core idea (DCI) element:

PS2.A: Forces and Motion

- ~~Newton's second law accurately~~ predicts changes in the motion of macroscopic objects. (HS-PS2-1)

In this lesson, students begin engaging with following crosscutting concept (CCC):

- **Cause and Effect:** Systems can be designed to cause a desired effect.

This element is a connecting thread throughout this unit and will be utilized in multiple lessons. In this lesson, students will start to brainstorm what parts of vehicle systems are designed to keep people safe. In Lesson 3, students look at specific design solutions related to reaction time. In Lesson 5, they consider designing systems for improving safety when road conditions are wet. In Lesson Set 2, students examine specific design criteria for seat belts and airbags (Lesson 9), crumple zones (Lesson 10-11), and speed limits (Lesson 12). At the end of the unit, this element is tied to how students consider how well they have answered the DQB questions and is assessed on the transfer task.

Where We Are NOT Going

Although trends vary by age, racial identity, socioeconomic status, and location, in Lesson 1 we have chosen to present data representative of the entire United States. As students progress through the unit, new science ideas will lead them to consider how existing disparities might affect these statistics. In Lesson Set 3, students will figure out that the safety features they have identified are not accessible to all drivers and passengers, and they will consider the impact of policy on the statistics they saw in Lesson 1.

LEARNING PLAN for LESSON 1

1 · EXPLORE A NEW PHENOMENON

5 min

MATERIALS: *Student Mindfulness Resource*, *Pre-Unit Letter Home*, Community Agreements

ADDITIONAL GUIDANCE

Supporting social and emotional well-being: This topic can be sensitive for those who have experienced injury, trauma, or loss due to vehicle collisions. Please read the materials preparation and the front matter for the unit before embarking on this lesson. Ensure that you send the *Pre-Unit Letter Home* to parents and guardians as well as show the "Student Content Advisory" slide **before** beginning the lesson. We recommend completing these tasks at least a week in advance.

The first day of this lesson begins and ends with a mindfulness exercise to support students in drawing awareness to any trauma they may hold related to the topic. We encourage you to also engage in these mindfulness moments with your students, attending to your social and emotional wellness. Consult with a school-based mental health professional, such as a counselor, if needed.

If there is time, consider weaving additional mindfulness activities into the unit; see *Student Mindfulness Resource* for suggestions.

Review the "Student Content Advisory" information. Remind students that the content of the lesson might be upsetting. You can bring up the "Student Content Advisory" slide again to do this. Be sure to read the slide aloud so the whole class is aware.

Introduce a new phenomenon and elicit initial ideas. Display **slide A**. Read the statistic on the top of the slide:

- *Car crashes are a leading cause of death in the United States for people aged 1–54.*

Cue students to reflect for 1 minute on the slide's questions and take roughly 1 additional minute to turn and talk to a partner about their ideas. Then ask them to quickly share their ideas with the class. ✱ Anticipated responses are shown in the table below, but be sure to accept and validate all serious ideas at this stage. There is no need to discuss or probe student ideas right now or to get anything specific out on the table.

Suggested prompt	Sample student response
What do we think makes driving so high risk?	Maybe how fast cars go.

✱ ATTENDING TO EQUITY

Universal Design for Learning: Allowing students to *express* their ideas using multiple modalities supports student ownership of their learning by giving students choice, access, and control in navigating their own understanding around the science ideas. Consider agreeing on a set of nonverbal signals to use as a class (e.g., head nods, thumbs up or down, ASL signs) for signaling nonverbal agreement, disagreement, and wondering or questioning as a way to ensure equitable participation by giving students additional modalities with which to *express* themselves.

✱ ATTENDING TO EQUITY

Ethical deliberation and decision making about socio-ecological phenomena: Throughout this unit, students are encouraged to consider how humans and nonhumans outside the vehicle might be impacted by decision making related to vehicle safety. Encourage students to think about not just the safety of the driver and passengers but also the safety of

	Maybe because they are so big now, they are more dangerous or deadly?
	Sometimes people are distracted, which isn't good if you're driving.
So what factors do you all think can make driving safer or can make driving more risky?	Speed.
	If the driver is paying attention.
	If you have a nice car with lots of safety features.
Who or what else should we take into account?	The passengers could be impacted.
	Maybe the other people on the road or the sides of the road.
	People in other cars if there is a collision between two cars.
	Maybe trees on the sidewalk or animals who cross the road.
	Too many cars might impact our land or waters. ✱

Pause for a moment of mindfulness. Present **slide B**. Give students 1-2 minutes to reflect individually about the prompts:

1. *How does it make you feel to think about car crashes, car safety, and traffic fatalities?*
2. *What concerns do you have about starting a unit about car crashes and car safety?*

Reiterate that students will not be asked to share their reflections unless they choose to do so.

Distribute the *Student Mindfulness Resource*. The *Student Mindfulness Resource* will serve as a resource for students to come back to throughout the unit if they feel overwhelmed or upset. After students have had a chance to look at the handout, ask what they, their caregivers, or people in their community have done in the past to ground themselves and stay mindful when a topic is upsetting. They can jot down their ideas on the last page of the handout, under prompt 1. They may talk about meditation, meals with family, recreational activities, breathing exercises, spending time with pets, and so forth. Accept all ideas and consider making a public record of some of these ideas at the front of the classroom.

pedestrians, trees, and animals. Students might also think more broadly about safety, considering the impact of larger vehicles on emissions, for example, and the resulting impact on lands and waters.

Considering how engineering solutions impact humans, nonhumans, and the natural world is an important part of the Learning in Places socio-ecological deliberation and decision-making framework, which involves sensemaking across seven dimensions. These dimensions include making sense of both human and more-than-human values, needs, and behaviors, in addition to making space for conversations about power and historicity. For more about this framework, please see the unit front matter.

ADDITIONAL GUIDANCE	There is no need to debrief this reflection. Although it is generally pedagogically productive to encourage students to connect their personal experiences to the content in science class, in this case it is more important to protect students who may have experienced a traumatic vehicle collision or lost a loved one to a car accident. This topic is very strongly relevant to most students' lives, and you do **not** need to proactively draw out their prior experiences to help them see that relevance.

Return to the Community Agreements. Present **slide C**. Pose the prompt, giving students several seconds of think time before asking for ideas:

- *How can we use our Community Agreements to protect ourselves and our classmates from emotional harm when discussing car crashes?*

Listen for ideas about treating others with respect and moving our science thinking forward without drawing on explicit descriptions. Accept all ideas that align with the values reflected in your class's Community Agreements.

2 · MAKE PREDICTIONS AND TEST THEM

10 min

MATERIALS: 1 sheet loose-leaf paper, science notebook, *Total Crashes Over Time (since 1996)*, chart paper, chart paper markers

Ask students to make a prediction on their own. Display **slide D**. Distribute a sheet of loose-leaf paper to each student to add to their notebook. Have them label the page "Exploring a New Phenomenon: Car Crashes over Time." Present the slide's first prompt for students to respond to individually on their paper, giving them no more than a minute to make a quick prediction:

- *In the United States, do you think driving has gotten safer over time or less safe? Why, and for whom?*

Take a quick poll about the predictions. Remain on **slide D**. Ask students to raise their hand if they think driving has gotten safer. Pause for a moment to allow them to get a sense of how many hands are raised. Ask a volunteer to share their reasoning.

Next, ask them to make explicit who or what they are thinking about when they consider safety. Expect that they will be thinking primarily about the driver and passengers of the car at this stage, but accept all ideas. Then ask students to raise their hand if they think driving has gotten less safe. Pause and then ask for another volunteer to elaborate on why and for whom.

Test predictions with a graph of crashes over time. Present **slide E**. Distribute the accompanying handout, *Total Crashes Over Time (since 1996)*. Ask students to examine the graph for a minute on their own, and then use the slide's prompts to elicit initial ideas about patterns: ✱ ✱

- *What patterns do you notice?*
- *Do any of these patterns surprise you?*

✱ ATTENDING TO EQUITY

For students who require additional scaffolds to identify the key patterns in the Key Ideas callout box, you can offer three additional prompts, one by one:

1. *Where does the line trend down?*
2. *Where does the line trend straight across?*
3. *Where does the line trend upward?*

✱ SUPPORTING STUDENTS IN DEVELOPING AND USING PATTERNS

Use this opportunity to highlight that the empirical evidence presented in the graphs

KEY IDEAS

Be sure that students identify the following **two key patterns**:

1. From 1995 to about 2010, the number of crashes went down.
2. From about 2010 until 2020, the number of crashes went back up.

Students may also notice these **additional patterns**:

- In 2020 the number of crashes went down steeply, but it appeared to come back up in 2021.
- The data are not in a straight line; it is a little messy.
- Maybe things flattened out after about 2016, but it is hard to tell.

ADDITIONAL GUIDANCE

Throughout this unit, students will be analyzing many different types of graphs. This lesson is a good opportunity to scaffold sensemaking. One option is to use the Identify and Interpret (I^2) strategy. See the *Modeling Identify Interpret Strategy* teacher reference for guidance on how to model this strategy. A student guide is also provided on the *Using Identify and Interpret Strategy (I2)* reference.

Make a record of trends the class noticed. Affix a blank piece of chart paper in front of the projection of the slide so the graph with its orange dots is projected onto the paper. For each pattern students identify, use a marker to sketch a trend line over the data, modeling how to identify trends during this lesson. Then label each trend line with a letter (A, B, C). In this way, record all the patterns that students identify, making sure to include the two key patterns specified in the Key Ideas callout box. Have students copy the class's patterns into the graph on *Total Crashes Over Time (since 1996)*.

ALTERNATE ACTIVITY

This can also be done by projecting onto a whiteboard and using dry erase markers. If you use a whiteboard or something else temporary, be sure all students have a chance to copy the trends onto *Total Crashes Over Time (since 1996)*.

If you use a monitor to share the slides instead of a projector, you can sketch the trends freehand on a sheet of chart paper affixed near the front of the room. Prepare the chart paper beforehand with graph axes to help students see how the two representations are related.

was needed in order to accurately identify the patterns in the number of crashes over time.

3 · ANALYZE DATA AND MAKE CONNECTIONS

15 min

MATERIALS: science notebook, 1 Data Jigsaw handout (either *Data Jigsaw A: Vehicle Miles Traveled* or *Data Jigsaw B: US Traffic Fatalities* or *Data Jigsaw C: Percent of Traffic Crashes with Fatalities and Injuries* or *Data Jigsaw D: Non-occupants Killed in Traffic Crashes* or *Data Jigsaw E: Registered Vehicles* or *Data Jigsaw F: Percent of Fatalities that Were Alcohol-Related*), whiteboard, dry erase markers (multiple colors)

Consider how to quantify safety. Say, *The number of car crashes (or vehicle collisions) is not the only way to think about safety*. Present **slide F**. On the same sheet of loose-leaf paper that students used to make predictions, ask students to respond to the prompts at the top of the slide:

- *What other data could help us quantify safety to test our predictions?*
- *Whose safety do these data take into account?*

Share with the class to motivate looking at more data. Ask students to briefly share out. Listen for ideas about counting or quantifying injuries, fatalities, types of vehicles, types of crashes, and so forth. Accept 3-4 ideas very quickly and then use them to motivate looking at more data by saying, *It sounds like there are some other data sets we could look at that might also tell us about whether driving has become more or less safe since the 1990s, and for whom.*

Analyze data in small groups. Present **slide G**. Organize students into groups of 2-4. To each group, distribute copies of either *Data Jigsaw A: Vehicle Miles Traveled*, *Data Jigsaw B: US Traffic Fatalities*, *Data Jigsaw C: Percent of Traffic Crashes with Fatalities and Injuries*, *Data Jigsaw D: Non-occupants Killed in Traffic Crashes*, *Data Jigsaw E: Registered Vehicles* ✱, or *Data Jigsaw F: Percent of Fatalities that Were Alcohol-Related*. Make sure at least one group is analyzing the data from each *Data Jigsaw* handout.

ALTERNATE ACTIVITY

If some students need additional time analyzing the data, use this as an opportunity to differentiate. *Data Jigsaw B: US Traffic Fatalities* and *Data Jigsaw D: Non-occupants Killed in Traffic Crashes* are very similar to the example done as a class and thus will be easier to scaffold by pointing to *Total Crashes Over Time (since 1996)*. *Data Jigsaw A: Vehicle Miles Traveled* and *Data Jigsaw F: Percent of Fatalities that Were Alcohol-Related* have new patterns, but they are fairly straightforward trends to identify. *Data Jigsaw C: Percent of Traffic Crashes with Fatalities and Injuries* and *Data Jigsaw E: Registered Vehicles* will be the most novel data sets for students.

Ask students to respond to the prompts on their handout and be ready to share:

1. *Discuss the trends that you notice in the graph above. Use different-colored markers to identify 1-3 trends over time.*
2. *On your group's whiteboard, sketch the axes of your graph and label them. Then copy the simplified trend lines that you identified onto the whiteboard. Be prepared to share the patterns you identified.*
3. *How do you think the patterns in the data are related to the patterns we saw in the number of crashes?*
4. *What new wonderings related to vehicle safety do these data bring up for you?*

✱ ATTENDING TO EQUITY

Data Jigsaw E: Registered Vehicles has graphs that use color to differentiate between two data sets on each graph. These colors have been selected to be colorblind friendly and have different enough shades that they should be discernible when printed in black and white. If they do not appear different enough in copies, consider projecting those graphs or providing them electronically so students can view them in color.

4 · KEEP TRACK OF PUZZLING PATTERNS IN A SCIENTISTS CIRCLE

15 min

MATERIALS: chart paper, chart paper markers

Form a Scientists Circle and share patterns. Present **slide H**. Have students assemble their chairs in a circle. Ask each group to spend no more than 1 minute sharing out the major patterns they noticed in the data. Record ideas on chart paper for a public record of "Puzzling Patterns" we would like to be able to explain. We will return to this chart in future lessons, so keep it on hand after class is done.

SCIENTISTS CIRCLE

You will form a Scientists Circle in many future lessons. If this is your first time, it is important to set up the agreements and logistics for forming, equitably participating in, and breaking down that space. As students get more comfortable with the Scientists Circle, they can move between it and other activity structures more quickly. Ideally, they should be able to see the slides and have access to a whiteboard, but if that is not possible, use only the whiteboard (or chart paper), which is where the more critical sensemaking will occur for the rest of the class.

Having students sit in a circle facing each other helps to build a sense of shared mission and community of learners working together. Returning to a Scientists Circle throughout the unit to take stock of what the class has figured out and where we need to go next is an important tool in helping students take on greater agency in steering the direction of their learning. You may want to point out that collaborative consensus building is a fundamental part of what scientists do.

Engage in mindfulness before leaving class. Present **slide I**. Again, ask students to think on their own for a moment or on their way out of class about how this topic makes them feel, using the prompts:

- *How did it make you feel to think about car crashes and car safety?*
- *What experiences or knowledge are you drawing on when you think about car crashes and car safety?*

Remind students that if at any point in the unit they need additional social or emotional support, they can approach you privately and you will help them connect to resources.

ADDITIONAL GUIDANCE

As the class identifies trends, many students will be tempted to make inferences about what might be causing these trends. If this happens, validate students' ideas as interesting but do not comment on their utility. Use these ideas to navigate to the next section by saying something like, *Interesting. We're going to shift gears next time and think about what might be going on here, so keep track of these ideas in your notebook for now.*

End of day 1

5 · NAVIGATE: TURN AND TALK ABOUT PUZZLING PATTERNS

3 min

MATERIALS: Puzzling Patterns poster

Turn and talk about Puzzling Patterns in a Scientists Circle. Begin by forming a Scientists Circle. Present **slide J**. Ask students to look back at our Puzzling Patterns poster. Pose the questions on the slide to engage them in navigating into the class period:

- *Which of the patterns that we identified last time do you think you can explain right now?*
- *Which is the most puzzling to you?*

6 · BUILD UNDERSTANDINGS ACROSS DATA SETS IN THE SCIENTISTS CIRCLE

18 min

MATERIALS: *Timeline of Vehicle Safety*, What can affect the outcome of a collision? poster, chart paper markers, Puzzling Patterns poster

Lead a Building Understandings Discussion about change across data sets. Display **slide K**. Use the prompts to lead a conversation in the Scientists Circle as shown in the table below. ✱

Suggested prompt	Sample student responses
How might one or more patterns be related to another or to the collision patterns we identified as a class?	Number of fatalities follows a similar pattern to total crashes over time, and so does non-occupant fatalities. Percent of crashes with fatalities has the opposite pattern as total crashes over time. People have been driving more trucks, so the cars on the road are maybe getting bigger, which could explain another graph. People have been driving more miles over time, which could explain another graph. Looks like alcohol use is not correlated with any other trends.

✱ STRATEGIES FOR THIS BUILDING UNDERSTANDINGS DISCUSSION

For each discussion type, the teacher takes a different stance in facilitation. Be explicit about your role in this discussion. Your role is to keep students focused on what we want to figure out, ensure equitable participation, press for evidence, and elevate ideas that the class agrees are important.

Before starting, say something like, *We aren't sharing our initial ideas now. Instead, we will base our ideas on evidence from a shared experience. My role in this discussion is to press for evidence, regardless of whether the ideas are right or wrong. So you might hear me ask, "Where did you see that in the data?" That does not mean you're wrong! It's my job to push us as a class to articulate the evidence we have to support the patterns we noticed.*

Are there time periods when changes happened across multiple data sets?	Something important seems like it is happening in the late 2000s that turns several trends around. Something must have happened in the 90s and 2000s to make driving safer. Something must have been happening in the 2010s to make driving more dangerous for those outside the car, but also to protect the people inside the car. In 2020, something weird happened across multiple data sets.
What might have happened at that time to cause these changes?	Maybe cell phone use could have gone up in the 2000s and 2010s. Maybe cars got safer then. Maybe people started wearing seat belts more because they passed a law.

Notice and wonder about a timeline of vehicle safety. Distribute the *Timeline of Vehicle Safety* to each student. Present **slide L**. Give students 2-3 minutes to discuss the timeline with an elbow partner in the Scientists Circle, using the slide's prompts:

- *What do you notice? What do you wonder?*
- *Do any of these events correspond to dates we identified across multiple data sets?*

Ask 2-3 partner pairs to share what they talked about. Accept and validate all ideas, listening for a diversity of noticings and wonderings. Students may notice that the iPhone was introduced right before the trends in the graphs change. They may wonder why the government left speed limit laws up to states. They may wonder whether advertising or ticketing is more effective for encouraging seat belt use. Encourage new ideas by asking, *Did anybody talk about something very different?*

Make a public record of design solutions and other important factors. After a few minutes, say, *It sounds like we already have some ideas about what could be causing some of these trends. We've identified some safety features that we think might be affecting collision outcomes. We've also identified other factors, like drivers on cell phones. Let's keep a public record of our ideas about what could affect collision outcomes so we can investigate some of them further and figure out if they can explain any of our national trends.*

Here are some follow-up prompts you might use in this discussion:

- *Where did you see that in the data?*
- *Can you say more about that pattern?*
- *Did anybody see a similar pattern in their data?*
- *How is the pattern you noticed similar to another pattern on our list of puzzling patterns? How is it different?*

✱ SUPPORTING STUDENTS IN THREE-DIMENSIONAL LEARNING

Take a moment to consider what makes something a design solution and not just a factor. Ask students what they think makes something a design solution. Listen for ideas about people making decisions on purpose to solve a problem. Help students see that a design solution doesn't just refer to physical objects, as it can also mean policy decisions or local enforcement of speed limits.

Present **slide M**. Read the text at the top:

- *Something is affecting the outcomes of vehicle collisions over time to create these patterns.*

Make sure everyone agrees with this statement. Then reveal the chart paper that you prepared before class titled "What can affect the outcome of a collision?" Use the prompts on the slide to elicit ideas and start recording them on the poster:

- *What design solutions do we think are most important in determining the outcome of a collision? Why?* ✱
- *What other factors might have an impact on the outcome of a collision? Why?*

Accept all ideas but don't worry about creating an exhaustive list. Anticipated ideas are listed below.

Design solutions

- seat belts
- airbags
- crumple zones
- crosswalks
- speed limits

Other factors

- distracted driving
- drunk driving
- road conditions (e.g., weather, potholes)
- driver experience
- pedestrians
- the size of other cars
- deer or other animals in the road

7 · MODEL COLLISIONS WITH TOY CARS

9 min

MATERIALS: 1 small toy car, 1 larger toy car, What can affect the outcome of a collision? poster, chart paper markers

Model three collision scenarios. Transition out of the Scientists Circle into group work, with 2-4 students per group. Present **slide N**. Distribute the *Modeling with Toy Cars* handout to guide student work. Distribute one smaller toy car (such as a compact or a smaller sedan) and one larger toy car (such as an SUV, a truck, or a larger sedan) to each group. Give groups a few minutes to model three collision scenarios and consider what new ideas this brings up about the two-car system.

Move around the room as students model the following scenarios with the toy cars, and record what they notice and wonder:

- Head-on, one car is stopped, one car is moving before the collision
- Head-on, both cars moving toward each other before the collision
- Rear-end, both cars moving in the same direction before the collision

Add to our public record. Take a minute to elicit any new ideas we want to add to the What can affect the outcome of a collision? poster, using the prompt on the bottom of the slide. This activity may bring up ideas about speed, mass, or the height of cars.

8 · DEVELOP INITIAL MODELS

15 min

MATERIALS: *Initial Model*, 1 sheet chart paper, chart paper markers (assorted colors)

Develop individual models. Present **slide O**. Distribute the *Initial Model*. Direct students to choose one or more design solutions or other factors from the list the class made, and then move through the prompt using that choice. They should use any combination of drawings, symbols, and words on the handout to explain how and why various design solutions or other factors might impact outcomes, both before and during a vehicle collision. Give students about 8 minutes to work on their individual models.

ASSESSMENT OPPORTUNITY

What to look for/listen for in the moment: Look for students to do the following:

- Identify and model safety features designed to change the physics of a vehicle collision (do not expect students to be able to explain **how** these features affect the collision yet). (CCC: 2.3)
- Use ideas about motion, size, speed, or forces to make connections between how the design solutions and other factors they model might affect specific trends that they see in the graphs (making a prediction). (SEP: 2.6; DCI: PS2.A.1, ETS1.A.2)

What to do: As students work on their models, circulate and ask questions such as these:

- *How does this factor or feature work together with the overall car system?*
- *What effects does this have on the outcome of the collision?* ✱
- *How is this factor's or feature's function causing or is correlated to that outcome of the collision?*
- *What evidence would we need to figure out more about the function of this system component?*

✱ SUPPORTING STUDENTS IN DEVELOPING AND USING CAUSE AND EFFECT

Throughout this unit, students will engage with CCC element 2.3, *Systems can be designed to cause a desired effect*, many times. Use the initial model work during this lesson as a way to assess students' prior knowledge on this element.

Building toward: 1.B Develop a model of a vehicle-driver system that includes safety components designed to alter the physics of a collision in order to predict the impact these components have on traffic safety statistics. (SEP: 2.6; CCC: 2.3; DCI: PS2.A, ETS1.A.2)

Develop group models on chart paper. Divide students into new groups of 3-4. Display **slide P**. Encourage groups to come to some consensus around important parts and interactions in the system, using the prompts on the slide:

- *Which design solutions or factors did each group member choose to include? Come to consensus around 1-3 that the group agrees are most important for determining the outcome of a potential collision.*
- *What other important parts did each group member include in the system? What interactions make these parts important for explaining what happens before and during a collision?*

After about 4 minutes, switch to **slide Q**. Direct groups to make a group model on chart paper using the prompts:

- *On chart paper, use any combination of drawings, symbols, and/or words to explain how and why the solutions and factors your group chose might impact outcomes.*
- *Consider what happens in the system before and during a vehicle collision.*
- *Your classmates should be able to understand your model without someone being there to explain.*

End of day 2

9 · GALLERY WALK PASS 1: COMPARE INITIAL MODELS

20 min

MATERIALS: science notebook, group model posters, M-E-F triangle poster (from *Earth's Interior Unit*)

Do a gallery walk to compare initial models. Have the group model posters hanging in the classroom for a gallery walk. Present **slide R**. As students come in, ask them to take their notebook and quietly begin moving around the classroom, considering the prompts on the slide:

1. *Which **design solutions** do you see included in multiple models?*
2. *What **other factors** related to the driver(s), the car(s), or the collision do you see included in multiple models?*
3. *Thinking back to what we figured out about breaking and deformation in the Afar unit, what representations or ideas related to **energy, forces, or matter** do you see represented in multiple models?*

Give students 10 minutes to move among posters and take notes.

Consider how energy, matter, and forces show up in the models. Present **slide S**. Bring the class together for 10 minutes to debrief the gallery walk, using the prompts as shown in the table below.

Suggested prompt	Sample student response
Which design solutions and other factors did you see in multiple models?	Seat belts, airbags, texting while driving, speed, car size, and so forth.
Thinking back to what we figured out about breaking and deformation in Earth's Interior Unit, what representations or ideas related to energy, forces, or matter did you see represented in multiple models?	Not much related to forces or energy. Maybe a few people drew forces of energy transfer using arrows, or described energy transfer in words. A few representations of motion which we recall from Afar are somehow related to forces, and which are a manifestation of energy transfer. Several groups represented matter changes, including breaking, crumpling, and deforming.

Point out that we were mostly focused on matter and physical parts of the system the first time around, and that maybe we didn't think as deeply about interactions, specifically energy transfer and unbalanced forces in the system. Say, *The M-E-F triangle has been powerful for helping us make sense of the motion of plates and resulting changes to Earth's crust. Maybe it can also help us organize our ideas about vehicle collisions.*

10 · GALLERY WALK PASS 2: LOOK FOR M-E-F

10 min

MATERIALS: 5 3x3 sticky notes (pink), 5 3x3 sticky notes (green), 5 3x3 sticky notes (purple), M-E-F triangle poster (from *Earth's Interior Unit*)

Do a second pass on the gallery walk with a partner. Present **slide T**. Direct students to pair up and tour the models again, this time looking for places where ideas from the M-E-F triangle could strengthen the explanation. They should use sticky notes as follows:

- pink stickies to identify possible matter transformations
- green stickies to identify possible energy transfers
- purple stickies to identify possible unbalanced forces

Remind students to write on each sticky to describe the matter transformation, energy transfer, or unbalanced forces involved. Each pair does not need to visit every poster, but make sure at least one pair visits each poster.

After 10 minutes ask students to bring their notebook to a Scientists Circle so we can come to consensus.

11 · DEVELOP AN INITIAL CONSENSUS MODEL

15 min

MATERIALS: Initial Consensus Model poster, chart paper markers (assorted colors)

Lead a Consensus Discussion. Reveal a sheet of chart paper titled "Initial Consensus Model" and explain that we will develop a consensus model explaining what happens before and during a collision that could affect safety. ✱ Present **slide U**. Use the prompts to guide the discussion: ✱

- *What parts and interactions in the system should we include?*
- *What M-E-F ideas should we include to explain how the design solutions and other factors that we identified might impact safety before and during a vehicle crash?*

ADDITIONAL GUIDANCE

Social and Emotional Learning (SEL): Some students may have experienced trauma related to distracted driving. Be mindful of any changes such as body language adjustments, intonation, and distraction. If a student seems to exhibit any changes, consider asking them privately and quietly if they would like to step out and see the counselor or take a moment to themselves for a break in the hallway or bathroom.

✱ ATTENDING TO EQUITY

Universal Design for Learning: Use *representations* like color coding and lettering. Although color coding is a useful way to quickly reference the trends, also including letters helps ensure accessibility for any student who may be colorblind. If you know you have colorblind students, consider a color palette that uses orange, blue, black, or dark brown, as these tend to be more easily distinguished by people who are colorblind.

✱ STRATEGIES FOR THIS INITIAL IDEAS DISCUSSION

As students share, areas of disagreement or uncertainty may emerge. If this happens, honor those student ideas by revoicing and/or recording them and create a convention, such as a question mark, to show that the class is uncertain.

End of day 3

12 · NAVIGATE: TURN AND TALK ABOUT THE INITIAL CONSENSUS MODEL

5 min

MATERIALS: Initial Consensus Model poster

Turn and talk about the Initial Consensus Model. Display **slide V**. Ask students to turn and talk and be ready to share about any one of the prompts:

- *Does our consensus model help explain*
    - *why crashes were decreasing in the 1990s?*
    - *why crashes have become more common after 2010?*
    - *why non-occupant fatalities have risen steeply since 2010?*
    - *why the percent of crashes with fatalities has been dropping since 2010?*

Elicit ideas. Listen for students to suggest that our consensus model explains some of the trends on the slide but not all, at least not very well. Point out that we still have a lot of questions about our consensus model.

13 · DEVELOP QUESTIONS FOR THE DRIVING QUESTION BOARD

7 min

MATERIALS: 2-3 3x3 sticky notes, permanent marker, pencil

Discuss what we need to know to advocate for solutions. Present **slide W**. Pose the question on the slide to guide a short class discussion about solutions:

- *What do we need to know more about in order to determine what kinds of solutions we could advocate for to make our community safer, inside and outside of vehicles?*

Accept all ideas and revoice them to encourage students to think about questions that will be productive toward real design solutions. Listen for ideas about data for our community specifically, about protecting local lands and waters, about additional events missing from our timeline, about safety features on cars, and about distracted driving or cell phone use.

Develop questions for the DQB. Present **slide X**. Remind students that we have considered these things:

- data on vehicle collisions
- a timeline of vehicle design solutions
- a consensus model using M-E-F thinking to explain how and why various design solutions or other factors might impact outcomes in a vehicle collision
- what we need to know to develop solutions for our own community

Ask students to think back on all that we have done and to develop some questions. Instruct them to record one question per 3x3 sticky note, using a thick marker, and put their initials on the back of each sticky in pencil. Give them about 5 minutes to develop questions.

ASSESSMENT OPPORTUNITY

What to look for/listen for in the moment: Look for students to do the following:

- Develop questions about how factors such as distracted driving, road safety, or vehicle design solutions (like seat belts, airbags, or automation) might affect collision outcomes. (SEP: 1.1, DCI: ETS1.A.2)
- Connect questions to specific patterns revealed in the empirical data. (CCC: 1.5)
- Ask questions about how changes in mass and velocity, among other variables, affect the outcomes of a collision (note that students will likely **not** use the appropriate scientific terminology at this point, and that is fine). (DCI: PS2.A.1)

What to do: As the class writes questions, circulate and verify with students that their questions can be answered with observations or investigations that can be done within the scope of the classroom and that they are related to the components of the system. Ask questions such as these:

- *What can we do to figure out the answer to your question? Can this be done within our classroom with data or evidence from an investigation or simulation?*
- *What questions do you have about how _____ relates to the overall system?*
- *What questions do you have about the effects and function of _____?*
- *Do you think _____ causes any changes to the car system as it collides with another car?*

Building toward: 1.A Ask questions that arise from careful analysis of data about correlations between vehicle collisions over time and changes within and outside of the vehicle-driver system, such as driver distraction, vehicle mass, and vehicle velocity, that can only be answered using empirical evidence. (SEP: 1.1; CCC: 1.5; DCI: PS2.A)

14 · BUILD THE DRIVING QUESTION BOARD

17 min

MATERIALS: DQB questions on 3x3 sticky notes, chart paper, chart paper markers, Initial Consensus Model poster, Community Agreements

Support students in building the rest of the DQB. Arrange students in a Scientists Circle with the Initial Consensus Model positioned where everyone can see it, and the sheet of chart paper titled "Driving Question Board (DQB)" accessible to create the DQB.

Display **slide Y**. Explain that students will take the lead on this process. Choose the first volunteer to begin and then have the class follow the process outlined on the slide. Step in when necessary to point students to some of the Community Agreements to encourage equitable participation. The slide's directions for assembling the DQB are as follows:

1. *With your class, gather around the DQB.*
2. *Choose a volunteer to go first. This student reads their question and then sticks it onto the DQB.*
3. *Raise your hand if you have a question that is similar or the same. The first person calls on the next person, who reads their question, says how it relates, and then sticks it onto the DQB near the first sticky.*
4. *Repeat step 2 until all similar questions in the room are stuck to the DQB.*
5. *Another student reads a new, unrelated question. Continue until everyone has at least one sticky on the DQB.*
6. *Choose a title for the DQB.*

Have students share their questions, moderating the process as needed, until all questions have been posted.

Title the DQB. You may need to facilitate the discussion to choose a title. Ask, *What is the big question we are trying to answer?* Listen for ideas about making driving safer, such as, "How can we make driving safer?" or "Why is driving so risky, and how can we fix it?" Write the question the class agrees on as the title at the top of the DQB.

Name clusters and make an Ideas for Investigations and Data We Need poster with them. Present **slide Z**. Still in a Scientists Circle, ask what we should name some of the major clusters that grew on our DQB. One cluster might be related to seat belts, for example, while another might be about distracted driving or a specific problem in the community.

Reveal the chart paper titled "Ideas for Investigations and Data We Need" and record 3-5 major cluster topics from the DQB, as shown on the slide. If there are more than four major clusters, you might need to make two posters. Leave enough room to fit 5-6 3x3 stickies under each topic.

15 · IDENTIFY RELATED PHENOMENA AND IDEAS FOR INVESTIGATIONS

16 min

MATERIALS: 2-3 3x3 sticky notes, Ideas for Future Investigations and Data We Need poster, chart paper markers, Related Phenomena poster

Consider related phenomena. Present **slide AA**. Still in the Scientists Circle, ask the class to consider phenomena other than vehicle collisions that we could help explain, or design problems that we could help solve, by answering these questions. Record student ideas on the piece of chart paper titled "Related Phenomena". Listen for ideas about protecting our bodies with gear during sports, preventing electronics from cracking with cases, plane or train collisions, egg drops, planetary landers, and so forth.

Develop ideas for future investigations and data. Preset **slide BB**. With a few minutes left in class, ask students to work on their own (or with an elbow partner) to record some ideas for data or investigations we need to help answer our questions and inform possible solutions. Have them record ideas on 3x3 stickies. Be ready to add these to the Ideas for Investigations and Data We Need poster under the cluster title, as shown on **slide BB**.

Read through the responses after class to help make connections in the next lesson. Anticipated ideas include the following:

- data on collisions in our community or for a certain type of location
- reaction time, distance, and vehicle speed measurements
- video or photos of collisions
- collision statistics data by vehicle type
- crash dummy measurements (motion, forces, damage)
- testing various vehicle collision conditions ourselves in a scaled-down system (e.g., two vehicles on a track with different speeds and masses)
- testing different types of vehicle materials ourselves and the effect on the collision in a scaled-down system (e.g., metal, plastic, other)
- testing the effects of adding seat belts, airbags, and so forth on the damage to a physical representation of a passenger in the vehicle (e.g., an egg, a clay ball)
- using a computer simulation to test the effects of different design solutions (seat belts, airbags, and so forth) on the people and the vehicle

Listen for ideas about distracted driving or other driver behavior, and be ready to point to them at the start of the next lesson.