Lesson 12: How can we use our models from across the unit to explain how vehicle systems can be designed to increase safety?

Previous Lesson *We analyzed crash test results from simulated collisions to understand how the crumple zone's rigidity and length influence occupancy safety. We used ideas about matter, energy, and forces to explain how the crumple zone design enhances collision safety.*

This Lesson

Putting Pieces Together, Problematizing

3 days

bairli1, Pixabay

We read conflicting arguments about speed limits and compare the science ideas presented in each. We construct a Gotta-Have-It Checklist to compile our ideas from across the unit. We use this list to develop explanations of how various criteria and design solutions are designed to increase vehicle safety, and we identify that priorities need to be considered. We then return to the speed limit arguments and consider societal impacts to complete our evaluation of the two arguments.

Next Lesson *We will use the Argument Comparison Tool to compare arguments relevant to our community using our science ideas as well as societal constraints and ethical issues. We will survey community members about local problems regarding transportation.*

BUILDING TOWARD NGSS

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

What students will do

12.A Evaluate and compare competing arguments related to policy decisions to change speed limits within driving systems based on scientific knowledge and principles, prioritized criteria, unequal effects, limitations (e.g., tradeoffs), constraints, and societal and ethical impacts. (SEP: 7.1; CCC: 2.4; DCI: ETS1.B.1)

12.B Identify multiple simple criteria in the complex vehicle-driver system that combine to determine the vehicle safety in collisions and organize the scientific ideas that explain how these criteria can be used to design safer vehicle-driver systems. Then apply ideas about forces and changes in motion to explain how prioritizing certain criteria could create a safer design. (SEP: 6.3; CCC: 2.3; DCI: PS2.A.1, ETS1.C.1)

What students will figure out

- There are many criteria that can be individually designed to collectively affect vehicle safety.
- Different arguments can be made on issues related to vehicle safety, and tradeoffs and societal impacts also need to be considered.

Lesson 12 • Learning Plan Snapshot

Part	Duration		Summary	Slide	Materials
1	4 min		**NAVIGATE** Display the advisory slide and acknowledge the lesson's potentially emotional content. Revisit as a class the idea that increasing speed reduces safety in driving.	A-C	*Speed Home Learning* from Lesson 3, *Survivability versus Velocity* from Lesson 11, Community Agreements poster
2	26 min		**COMPARE AND EVALUATE ARGUMENTS** Introduce two different arguments about speed limits. Revisit Community Agreements. Read and annotate the arguments as a class and complete *Science-Ideas Argument Comparison* to compare the science ideas in the two arguments.	D-J	*Argument 1A: Maintaining Speed Limits*, *Argument 2A: Lowering Speed Limits*, *Science-Ideas Argument Comparison*, alternate leveled readings (optional, see equity callout), projected copy of *Science-Ideas Argument Comparison*, Community Agreements, dry erase markers
3	10 min		**REFLECT ON COMPARING ARGUMENTS** Answer the last prompt on *Science-Ideas Argument Comparison* to reflect on the importance of speed limit decisions. Reflect on the experience of comparing the arguments.	K-L	*Science-Ideas Argument Comparison*, projected copy of *Science-Ideas Argument Comparison*
4	5 min		**REVISIT THE DRIVING QUESTION BOARD** Review the DQB and identify questions that we can now answer.	M	Driving Question Board
					End of day 1
5	24 min		**DEVELOP A GOTTA-HAVE-IT CHECKLIST** Individually review unit materials. Gather in a Scientists Circle to construct a Gotta-Have-It Checklist for explaining vehicle safety.	N-Q	3x3 sticky notes, permanent marker, *Engineering Progress Tracker*, Gotta-Have-It Checklist poster, chart paper markers, Force and Motion Relationships poster from Lesson 6 and updated in Lesson 9, M-E-F triangle poster, Momentum Relationships poster from Lesson 6, Crumple Zones and M-E-F from Lesson 11

6	7 min		**REFLECT ON LEARNING** Annotate the Gotta-Have-It Checklist with sticky dots to indicate certainty and uncertainty about the ideas. Reflect on learning individually and with a partner.	R-S	sticky dots (red), sticky dots (green), Gotta-Have-It Checklist poster, Initial Consensus Model poster from Lesson 1
7	14 min		**CONSTRUCT EXPLANATIONS OF SAFETY CRITERIA** Distribute *Explaining Safety Designs* and guide students through individually using the Gotta-Have-It Checklist to construct and revise explanations of how design solutions connect to safety.	T-V	*Explaining Safety Designs*, Gotta-Have-It Checklist poster

End of day 2

8	3 min		**NAVIGATE** Orient the class to the ideas of tradeoffs and limitations to motivate revisiting the speed limit arguments with a societal lens.	W	*Explaining Safety Designs*
9	22 min		**COMPARE SOCIETAL IMPACTS OF ARGUMENTS** Guide the class through comparing the speed limit arguments from a societal perspective to highlight that sometimes science ideas don't provide clear answers.	X-Z	*Societal-Impacts Argument Comparison*, *Science-Ideas Argument Comparison*, *Argument 1A: Maintaining Speed Limits*, *Argument 2A: Lowering Speed Limits*, projected class copy of *Societal-Impacts Argument Comparison*
10	5 min		**UPDATE THE DRIVING QUESTION BOARD** Bring students together to review the DQB and add new questions about implementation of design and policy for vehicle safety.	AA	3x3 sticky notes, permanent marker, Driving Question Board
11	15 min		**COMPLETE THE ELECTRONIC EXIT TICKET** Facilitate students individually completing an Electronic Exit Ticket.	BB	computer with access to https://docs.google.com/forms/d/11qXSTaY2m8I1PUbaYR17yqZVvlVEfS1TOsxI4VTFVOY/copy

End of day 3

Lesson 12 • Materials List

	per student	per group	per class
Lesson materials	• *Speed Home Learning* from Lesson 3 • *Survivability versus Velocity* from Lesson 11 • *Argument 1A: Maintaining Speed Limits* • *Argument 2A: Lowering Speed Limits* • *Science-Ideas Argument Comparison* • alternate leveled readings (optional • see equity callout) • 3x3 sticky notes • science notebook • permanent marker • *Engineering Progress Tracker* • sticky dots (red) • sticky dots (green) • *Explaining Safety Designs* • *Societal-Impacts Argument Comparison* • computer with access to https://docs.google.com/forms/d/11qXSTaY2m8I1PUbaYR17yqZVvlVEfS1T0sxI4VTFVOY/copy		• Community Agreements poster • projected copy of *Science-Ideas Argument Comparison* • Community Agreements • dry erase markers • Driving Question Board • Gotta-Have-It Checklist poster • chart paper markers • Force and Motion Relationships poster from Lesson 6 and updated in Lesson 9 • M-E-F triangle poster • Momentum Relationships poster from Lesson 6 • Crumple Zones and M-E-F from Lesson 11 • Initial Consensus Model poster from Lesson 1 • projected class copy of *Societal-Impacts Argument Comparison*

Materials preparation (45 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.

Prior to day 1

Social and Emotional Learning: This lesson involves engaging in arguments around speed limits and safety that may cause strong reactions for some individuals. Be sure to provide students with an advisory warning and remind them of the resources they have available to them for support. Have the Community Agreements poster visible.

Prepare a copy of *Science-Ideas Argument Comparison* that can be projected and filled in during the class discussion. If projection is not available, copy the handout onto the board to fill in. Students will simultaneously fill in their own copies, so the class copy will not need to stay posted in the classroom.

Have the DQB available.

Prior to day 2

Title a piece of chart paper: "Gotta-Have-It Checklist".

Make sure the following posters are visible for student reference:

- Force and Motion Relationships poster from Lesson 6 and updated in Lesson 9
- M-E-F triangle poster
- Momentum Relationships poster from Lesson 6
- Crumple Zones and M-E-F from Lesson 11
- Initial Consensus Model poster from Lesson 1

Prior to day 3

Prepare a copy of *Societal-Impacts Argument Comparison* that can be projected and filled during the class discussion. If projection is not available, copy the handout onto the board so that it can be filled in. Students will be simultaneously filling in their own copies, so the class copy will not need to stay posted in the room.

Before class, make a copy of the Electronic Exit Ticket found at the following link: https://docs.google.com/forms/d/11qXSTaY2m8I1PUbaYR17yqZVvlVEfS1T0sxI4VTFVOY/copy. Share the link to the **copy** with students, **not** the link provided here; if you share the original link, that will create a new copy for each student, and you will not have access to their responses. See the reference *Electronic Exit Tickets* for more information about how to make this copy.

Lesson 12 • Where We Are Going and NOT Going

Where We Are Going

In this lesson, students collect the ideas they have developed across the unit and revisit the unit's anchor phenomenon through explaining how criteria and design solutions impact vehicle safety. Specifically, students will be revisiting the idea of speed and changes in velocity. This builds off their work in Lesson 3 with speed limits and avoiding collisions and the unequal changes in velocity in collisions between unequal mass vehicles in Lesson 6.

This lesson is reinforcing ideas related to the following disciplinary core idea (DCI):

- **PS2.A Forces in Motion:** Newton's second law accurately predicts changes in the motion of macroscopic objects. (HS-PS2-1)

In addition to the above DCI, this lesson is designed to coherently build ideas related to the following ETS (DCIs), which will be further developed in the third lesson set:

- **ETS1.B.1 Developing Possible Solutions:** When evaluating solutions, it is important to take into account a range of constraints, including ~~cost~~, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (HS-ETS1-3)
- **ETS1.C.1 Optimizing the Design Solution:** Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (tradeoffs) may be needed. (HS-ETS1-2) (secondary to HS-PS1-6) (secondary to HS-PS2-3)

On day 1 and day 3, during the comparison and evaluation of arguments regarding speed limits, students consider multiple constraints. These constraints are not limited to safety but also consider social and environmental impacts through the lens of questions generated from the Learning in Places Ethical Deliberation and Decision-Making in Socio-Ecological Systems framework. Students also use "should we" questions based on this framework to consider why values might guide the prioritization of certain criteria or constraints over others. See http://learninginplaces.org/frameworks/wonderings-should-we-and-investigation-framework/ for more information about "should we" questions.

This Learning in Places framework helps guide sensemaking and decision making based on the values of different places, communities, and cultures. Moving forward, this framework will be woven into each argumentation and evaluation moment where *Science-Ideas Argument Comparison* is used to dive deeper into DCIs ETS1.B and ETS1.C. Students will move toward proficiency and independence on the use of these DCIs over the course of the next three lessons.

The argument comparison and evaluation in this lesson is designed to support students toward the Next Generation Science Standards (NGSS) Nature of Science Understanding (Appendix H). The relevant understanding elements read as follows:

- **Science is a human endeavor:** Science and engineering are influenced by society and society is influenced by science and engineering.
- **Science addresses questions about the natural and material world:** Science and technology may raise ethical issues for which science, by itself, does not provide answers and solutions.
- **Science addresses questions about the natural and material world:** Science knowledge indicates what can happen in natural systems--not what should happen. The latter involves ethics, values, and human decisions about the use of knowledge.
- **Science addresses questions about the natural and material world:** Many decisions are not made using science alone, but rely on social and cultural contexts to resolve issues.

Students encounter and/or co-construct ideas around several terms and may decide to add the following words to their Personal Glossary during this lesson: *tradeoff, limitation.* Do not ask students to define or keep track of any words until after the class has developed a shared understanding of their meaning.

Where We Are NOT Going

HS-ETS1-3 and ETS1.B.1 mention cost as a constraint. Due to the varying base costs, installation costs, and vehicle costs across the broad fleet of what exists on our roads today, it is difficult to quantitatively use this metric for evaluation. Instead, cost is considered qualitatively as we engage in argument about designing for vehicle safety. All other aspects of these DCIs will be discussed at some point during the next three lessons.

LEARNING PLAN for LESSON 12

1 · NAVIGATE

4 min

MATERIALS: *Speed Home Learning* from Lesson 3, *Survivability versus Velocity* from Lesson 11, Community Agreements poster

Acknowledge and validate emotions. Display **slide A**. Review the advisory on the top of the slide:

- *In this lesson, we will be discussing decisions made around vehicle safety. Some individuals may have strong responses to these arguments.*

Remind students of the resources available to them and that they need to approach conversations with respect, guided by your class's Community Agreements.

Revisit velocity and survivability data. Display **slide B**. Orient students to the graph and ask them to get out their *Survivability versus Velocity* exit ticket from last class. Re-pose the prompts on the slide:

- What effect does increasing velocity have on likelihood of survival?
- What can a driver do before a collision to reduce their risk of injury?

Look for students to say that above a certain velocity, increasing velocity decreases likelihood of survival and that drivers can either drive slower or brake to slow down before a collision.

Connect back to Lesson 3 home learning. Display **slide C**. Say, *Back in Lesson 3, we asked our families, friends, or community members about speed limits in our community.* Use the prompts on the slide to have students turn and talk:

- *Take out your Speed Home Learning handout from Lesson 3.*
- *Review your notes with a partner.*

After a minute or so, have a couple pairs share ideas that they had about speed limits from their *Speed Home Learning* handout from Lesson 3.

2 · COMPARE AND EVALUATE ARGUMENTS

26 min

MATERIALS: *Argument 1A: Maintaining Speed Limits*, *Argument 2A: Lowering Speed Limits*, *Science-Ideas Argument Comparison*, alternate leveled readings (optional, see equity callout), projected copy of *Science-Ideas Argument Comparison*, Community Agreements, dry erase markers

Read arguments about speed limits. Say, *Speed limits are one way that policy decisions can affect vehicle safety. Let's use the science ideas we've developed across this unit to evaluate some arguments about speed limits.*

✱ **ATTENDING TO EQUITY**

Project **slide D**. Distribute *Argument 1A: Maintaining Speed Limits* and *Argument 2A: Lowering Speed Limits* ✱. As a class, read both arguments together. As the arguments are being read aloud, ask students to annotate any claims, science ideas, and data or evidence that the authors used in their arguments.

Revisit the Community Agreements and select a focal agreement for the day. Project **slide E**. Point out that these arguments have very different viewpoints. Because of this, our class may have different opinions on the arguments, and we need to make sure to follow our Community Agreements as we compare and evaluate these arguments.

Direct the class to look back at the list of agreements. Ask students to identify one agreement that we can focus on as we engage in this process. Remind them that this should be an agreement that helps us engage in productive discourse. Give the class a couple minutes to discuss and choose the focus agreement. Ask them to justify why that focus is important for our conversation. Rewrite this focus somewhere highly visible, such as the whiteboard, and reference this agreement when students begin to have disagreements during the following discussions.

ADDITIONAL GUIDANCE

Social and Emotional Learning: Engaging in argumentation about speed limits may cause some individuals to have a strong reaction related to past trauma. It is important to acknowledge this possibility as a class and remember to be respectful when disagreeing. Remind students that when we engage in argumentation we are evaluating ideas, not the people expressing those ideas.

Compare written arguments. Distribute *Science-Ideas Argument Comparison* and display the class copy. Tell students that we will work through this evaluation as a class and also record information on our personal copies of *Science-Ideas Argument Comparison*. Explain that we will continue to use this tool to evaluate arguments as we progress through the unit and find areas of controversy, and this will serve as an example moving forward. Encourage students during this process to mark up their copy and make notes about anything that helps them understand what the question is asking or how to use the tool.

Display **slide F**. Orient students to the first two questions on *Science-Ideas Argument Comparison* and the slide:

- *What is the problem that these arguments are trying to solve?*
- *Why is it important to compare arguments?*

Give students a couple of minutes to discuss and answer the questions with a partner. Then ask a few pairs to share their ideas. Determine that we are evaluating these arguments to understand whether we should lower speed limits. Any variation of this answer is acceptable, but look for students to identify that the question should start with the word "should." Make this explicit by saying, *This is a "should we" question. There are a lot of important "should we" questions out there that we can use science and engineering to address.* Students should determine that this issue is important to understand because it affects the safety of everyone on the roads, among other things. Write a shared version of the answers on the class copy of *Science-Ideas Argument Comparison*.

Argument 1A: Maintaining Speed Limits and *Argument 2A: Lowering Speed Limits* are readings written at the 11th grade reading level (lexile level 1210-1400). Alternative versions are provided at a 9th grade reading level (lexile level 1010-1200): *Argument 1B: Maintaining Speed Limits* and *Argument 2B: Lowering Speed Limits* and at a 6th grade reading level (lexile 610-800): *Argument 1C: Maintaining Speed Limits* and *Argument 2C: Lowering Speed Limits*.

✱ ATTENDING TO EQUITY

Building classroom culture: It is important to organize activities in ways that create opportunities for students to engage in meaningful, accountable talk by emphasizing socially safe activity structures (e.g., small-group or partner work before a class discussion). This is especially beneficial to multilingual students. For this reason, partner talk or small-group talk should precede whole-group discussion whenever possible to give students an opportunity to share their ideas with one or two peers before going public with the whole class.

Then ask students to read the questions along the far-left column of the table on *Science-Ideas Argument Comparison*.

Review the suggested responses. Display **slide G**. Read the instructions on the slide:

- *Read the claims, science ideas, data or evidence, and connections to our investigations that have been presented in the first column of the Science-Ideas Argument Comparison handout.*

Give students a few minutes to read through the suggested responses.

Compare annotations to suggested responses. Display **slide H**. Read the instructions on the slide:

- *Review your annotations on the Argument 1A: Maintaining Speed Limits handout and the example, filled-out column on the Science-Ideas Argument Comparison handout.*
    - *How does what you annotated align with what was suggested in the table?*

Give students a few minutes to complete the task with a partner, then ask a few pairs to share their ideas. Create space for students to suggest additional ideas to include in the Argument #1 column, and add these to the class copy.

ADDITIONAL GUIDANCE

As students work through the argument comparison, they may need support in understanding the questions in addition to the prefilled example responses. Use the following guidance to help build their understanding.

Write the argument claims here.

- Explain that this space is meant to be an area where students can quickly write up a description of the argument or design that was made.
- This allows us to better define the argument or design solution and gives us a place to record what each design or argument is about in case they need to reference it later.

What key science ideas have we developed that support or refute this argument?

- Explain that this is a place for students to use our larger science ideas to support or refute the aspects of the argument or design.
- This row may contain information that both supports and refutes parts of the argument or design.
- In a later row, we will get more specific and try to tie data from our investigations to the argument or design solution.

What data, if any, does the author use as evidence to support this particular argument?

- Explain that this area is meant to record data cited by the author. These data can be from

investigations done by the author or others, and it might also be data not directly related to our science ideas.
- These data may be linked to societal wants and needs as well. Tell students that this information will be recorded here, but later the *Societal-Impacts Argument Comparison* handout will really dive into the societal aspect of our arguments and design solutions.

What data do we have from our investigations that could help support or refute this argument? If none, explain why our data are not relevant to this decision.
- Explain that this is a place for students to use ideas from the argument or design solution itself and from their science notebook, the classroom artifacts on the walls, or any other classroom learning to support or refute the aspects of the argument or design.
- This row may contain information that both supports and refutes parts of the argument or design.

Analyze a written argument. Display **slide I**. Tell students that we are now going to complete the second column of the table to evaluate *Argument 2A: Lowering Speed Limits*. Read the instructions on the slide:

- *Review your annotations on the Argument 2A: Lowering Speed Limits handout and fill out the second argument column of the table on the Science-Ideas Argument Comparison handout.*

Give students a couple of minutes to complete the second column in partners, and then have them share their ideas with the class. ✱

Ask students to cite specific parts of the text to support their answer. Prompt them to write on their handout as the class chart is being completed. See the *Argument Comparison Keys* for possible responses. It is OK if students bring up additional ideas for each box. Record these additional ideas as long as they fit with the prompt being used.

ADDITIONAL GUIDANCE

As students complete *Science-Ideas Argument Comparison* and *Societal-Impacts Argument Comparison*, pay attention to the clarifying questions being asked. Make sure to honor and document any questions and clarifications and make notes on the class copies to help support students in evaluating each design or argument from the viewpoints of science and society. During this lesson a large amount of time is spent on this process in a whole-group context. This is because students will continue to utilize comparison using these ideas and related scaffolds over the next three lessons to analyze arguments and design solutions. Students will eventually be expected to consider these prompts individually as they compare two design solutions on the *Pedestrian Solutions* transfer task in Lesson 15.

Compare evaluations of arguments. Display **slide J**. Orient students to the first prompt below the table on *Science-Ideas Argument Comparison* (and on the slide):

- *Compare your evaluations of the two arguments. Which argument or design has the most merit from a science perspective, and why?*

Give students a couple of minutes to talk about this prompt with a partner. Then take another couple of minutes to discuss as a class. See *Argument Comparison Keys* for example student responses. Write a shared version of the answers on the class copy of *Science-Ideas Argument Comparison*.

3 · REFLECT ON COMPARING ARGUMENTS

10 min

MATERIALS: *Science-Ideas Argument Comparison*, projected copy of *Science-Ideas Argument Comparison*

Display **slide K**. Orient students to the final two prompts on *Science-Ideas Argument Comparison* (and on the slide):

- *Why is the decision to either lower speed limits or maintain them important?*
- *Why is understanding the science behind speed limits important for members of our community?*

Give students a few minutes in pairs to answer the questions and then a couple of minutes for pairs to share with the class. Record the shared responses on the projected copy of *Science-Ideas Argument Comparison*.

ASSESSMENT OPPORTUNITY

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

- Cite key science ideas and data presented from written arguments and their investigation data which support the claims of the authors about the effects of a speed limit change. (SEP: 7.1; CCC: 2.4)
- Compare two arguments and judge which one has the strongest evidence from a science perspective while considering criteria and constraints related to unequal effects of speed limits. (SEP: 7.1; CCC: 2.4; DCI: ETS1.B.1)

See *Argument Comparison Keys* for example student responses.

What to do: During discussion, if students are not identifying information for each box, prompt them to look back at the readings for any differences in ideas between them and consider how these differences might influence the completion of the boxes.

When reviewing individual work after class, provide feedback on the level of detail and clarity. On Day 3 students will be completing *Societal-Impacts Argument Comparison*, which is very similar in structure to

Science-Ideas Argument Comparison. They also complete the same table for different arguments in the next lesson. Providing written guidance now can help students understand the expectations as they move forward.

Building toward: 12.A.1 Evaluate and compare competing arguments related to policy decisions to change speed limits within driving systems based on scientific knowledge and principles, prioritized criteria, unequal effects, limitations (e.g., tradeoffs), constraints, and societal and ethical impacts. (SEP: 7.1; CCC: 2.4; DCI: ETS1.B.1)

Debrief comparing arguments. Regroup the class and suggest that we talk about the evaluation process we just completed. Display **slide L**. Read the discussion prompts:

- *How did breaking down the claims, science ideas, and data and evidence help you evaluate arguments?*
- *How did it feel to compare and evaluate opposing arguments relating to safety?*

Discuss the prompts as a class. Highlight any student ideas about the evaluations being incomplete with just the science ideas, as these will help on day 3 to motivate revisiting the arguments from a societal perspective.

Collect *Science-Ideas Argument Comparison* to provide individual feedback.

4 · REVISIT THE DRIVING QUESTION BOARD

5 min

MATERIALS: Driving Question Board

Identify DQB questions we can now answer. Display **slide M**. Say, *So, it seems that our science ideas from across the unit are helpful in considering decisions related to vehicle safety. Let's revisit our DQB and look for questions we can now answer.*

Give students some time to individually review the DQB and identify questions they can now answer. Then take a few minutes to have them share as a class.

End of day 1

5 · DEVELOP A GOTTA-HAVE-IT CHECKLIST

24 min

MATERIALS: 3x3 sticky notes, science notebook, permanent marker, *Engineering Progress Tracker*, Gotta-Have-It Checklist poster, chart paper markers, Force and Motion Relationships poster from Lesson 6 and updated in Lesson 9, M-E-F triangle poster, Momentum Relationships poster from Lesson 6, Crumple Zones and M-E-F from Lesson 11

Motivate the Gotta-Have-It Checklist. Say, *We were comparing and evaluating arguments using the science ideas we have developed and noted that we can answer some more of our DQB questions.* Suggest that we compile our ideas into a Gotta-Have-It Checklist to help us as we continue to evaluate arguments and design solutions that help us answer our unit question of "What can we do to make driving safer for everyone?"

Display **slide N**. Say, *We have developed a lot of science ideas so far, but let's start with one important idea.* Have students turn and talk about the prompt:

- *If you had to choose, which science idea that we have developed in this unit is most important for explaining how vehicle systems can be designed to increase safety?*

Clarify that a vehicle system can include the driver and other factors such as speed limits.

After a few minutes, ask students to share their initial ideas. Don't go into too much detail now, as this will come later. The goal in this moment is to refresh students' memories about ideas from throughout the unit.

Review resources from the unit. Display **slide O**. Distribute sticky notes and markers. Ask students to collect unit artifacts to review such as their *Engineering Progress Tracker* and other notes or handouts. Give them about 5 minutes to look through these and public artifacts, such as posters, and to use sticky notes to draft an initial Gotta-Have-It Checklist for explaining how vehicle systems can be designed for safety.

ADDITIONAL GUIDANCE	Students work individually first so that all students are given the opportunity to synthesize the evidence and formulate their ideas. This part is important so that all students are prepared to defend their ideas, evaluate one another's ideas, and consider their ideas in the context of others' ideas.

Display **slide P**. Say, *Before we come together as a group, let's check in on our ideas with a partner.* Give students a couple of minutes to turn and talk.

Construct a Gotta-Have-It Checklist in a Scientists Circle. Display **slide Q**. Have students bring their sticky notes and gather in a Scientists Circle. Display the piece of chart paper titled "Gotta-Have-It Checklist". Ask them to share their ideas in a similar structure to building the Driving Question Board: when one student adds an idea, then other students with similar ideas group their sticky notes with that idea and that idea is discussed. Encourage them to create and label groupings of ideas. See *Gotta-Have-It Checklist Guide* for an example list and guiding prompts that can be used to help students fill in gaps.

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

OPPORTUNITY

- Identify multiple criteria and design solutions within vehicle systems that can be designed to affect safety. (CCC: 2.3; DCI: ETS1.C.1) For example:
  - distraction
  - speed or velocity
  - mass of vehicle
  - braking force
  - seat belts
  - airbags
  - crumple zone rigidity
  - crumple zone length
- Connect the relationships between force and changes in motion to how these criteria and design solutions can be designed to increase safety. (SEP: 6.3; CCC: 2.3; DCI: PS2.A.1)

What to do: If students are struggling to pull together the big ideas from the unit, use the prompts and ideas in *Gotta-Have-It Checklist Guide* to help them consider what connections can be made from class investigations and activities.

Building toward: 12.B.1 Identify multiple simple criteria in the complex vehicle-driver system that combine to determine the vehicle safety in collisions and organize the scientific ideas that explain how these criteria can be used to design safer vehicle-driver systems. Then apply ideas about forces and changes in motion to explain how prioritizing certain criteria could create a safer design. (SEP: 6.3; CCC: 2.3; DCI: PS2.A.1, ETS1.C.1)

6 · REFLECT ON LEARNING

7 min

MATERIALS: sticky dots (red), sticky dots (green), Gotta-Have-It Checklist poster, Initial Consensus Model poster from Lesson 1

Display **slide R**. Have students consider the prompts:

- *What is one of our Gotta-Have-It science ideas that you are confident about?*
- *What is one of our Gotta-Have-It science ideas that you are still figuring out?*

As students return to their seats, have them use green and red sticky dots to mark the Gotta-Have-It Checklist poster with one idea they are confident about and one they are still figuring out.

Reflect on our learning. Display **slide S**. Direct students' attention to the Initial Consensus Model poster from Lesson 1. Give them a couple of minutes to individually consider the model and complete the sentence stem (mentally or written): *I used to think _____, but now I know _____.*

Then have them turn and talk with a partner to share their reflections.

7 · CONSTRUCT EXPLANATIONS OF SAFETY CRITERIA

14 min

MATERIALS: *Explaining Safety Designs*, Gotta-Have-It Checklist poster

Construct explanations of criteria. Display **slide T**. Say, *Let's use our Gotta-Have-It Checklist to write some explanations of some of the criteria and design solutions we have been investigating over this unit.* Distribute *Explaining Safety Designs* to each student and orient them to the first prompt on the handout and the slide:

- *Select one criterion or design solution that we have investigated in this unit. Apply the ideas from our Gotta-Have-It Checklist to explain how this criterion or design solution can be optimized to increase vehicle safety.* ✱

Provide and receive feedback. Say, *In order to strengthen our shared understanding and our explanations, we are going to share our explanations and give and receive feedback from each other. Then you will have an opportunity to revise your explanation.*

Display **slide U**. Introduce and explain the TAG Feedback protocol: Tell something you like, Ask a question, Give a suggestion.

Review the further instructions on the slide:

- *First, find a partner who chose the same or similar criterion or design solution.*
    - *Share your explanations and provide TAG feedback.*
- *Next, group up with another pair that chose a different criterion or design solution.*
    - *Share your explanations and provide TAG feedback.*

Give students about 5 minutes to complete the feedback pairs and groups.

Revise our explanations. Display **slide V** and ungroup students. Ask students to use the feedback to revise their explanation and to complete the second prompt on *Explaining Safety Designs*. Give them the remaining time to complete the revisions and second prompt and then collect *Explaining Safety Designs*.

✱ SUPPORTING STUDENTS IN DEVELOPING AND USING CAUSE AND EFFECT

Students have been engaging with CCC element 2.3, *Systems can be designed to cause a desired effect*, throughout this unit. Look for students to make this concept explicit in their explanations. If students are struggling, use probing questions such as:

- What is the desired effect when optimizing a design?
- How is this system being designed to cause a specific result or effect?

ADDITIONAL GUIDANCE	If students struggle to understand what a negative effect could be, you can use the example of crumple zone length, where if we made the crumple zone super long, cars wouldn't fit into places or be maneuverable.

Collect *Explaining Safety Designs* to review student responses.

ASSESSMENT OPPORTUNITY

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

- Apply the relationships between force and changes in motion and the relationships between different parts of the vehicle system to construct an explanation about how one criterion or design solution can specifically be designed to increase safety. (SEP: 6.3; CCC: 2.3; DCI: PS2.A.1)
- Identify possible unanticipated effects and/or tradeoffs of changing one or more of these criteria and how this may impact how criteria should or shouldn't be prioritized. (SEP: 6.3; DCI: ETS1.C.1)

What to do: If students are having difficulties identifying unanticipated effects and/or tradeoffs, have a class discussion of topics that could be considered, such as costs, effects on the environment, availability to all, and the like, to help students move forward in their thinking.

Building toward: 12.B.2 Identify multiple simple criteria in the complex vehicle-driver system that combine to determine the vehicle safety in collisions and organize the scientific ideas that explain how these criteria can be used to design safer vehicle-driver systems. Then apply ideas about forces and changes in motion to explain how prioritizing certain criteria could create a safer design. (SEP: 6.3; CCC: 2.3; DCI: PS2.A.1, ETS1.C.1)

End of day 2

8 · NAVIGATE

3 min

MATERIALS: *Explaining Safety Designs*

Motivate consideration of societal impacts. Return *Explaining Safety Designs* to students. Say, *We left off last class considering how optimizing one criterion may have negative effects that could impact whether it can be prioritized.* Connect to some ideas that students have on *Explaining Safety Designs* that aren't directly related to science ideas, such as crumple zones being too long, causing cars to not be able to make turns or fit in parking spots.

Display **slide W**. Say, *Let's consider these other effects and how they can affect design decisions or policy arguments.* Have students turn and talk about the prompt on the slide for about 2 minutes:

- *What constraints and expectations in real life might affect how we should apply science ideas to make vehicles safer?*

After students turn and talk, ask a few pairs to share their ideas. Highlight ideas that are connected to societal norms and impacts on the environment, animals, or people other than drivers.

9 · COMPARE SOCIETAL IMPACTS OF ARGUMENTS

22 min

MATERIALS: science notebook, *Societal-Impacts Argument Comparison*, *Science-Ideas Argument Comparison*, *Argument 1A: Maintaining Speed Limits*, *Argument 2A: Lowering Speed Limits*, projected class copy of *Societal-Impacts Argument Comparison*

Compare and evaluate the speed arguments from a societal lens. Say, *It sounds like there are a lot of constraints on design when we think about how these solutions will play out in real society. Let's make sure we thought about all these constraints when we were looking at the speed limit arguments. I have another part of the comparison tool that we can use to compare the speed limit arguments that can help us expand how we think about societal impacts.*

Display **slide X**. Return *Science-Ideas Argument Comparison* and distribute *Societal-Impacts Argument Comparison* to each student and project the class copy of *Societal-Impacts Argument Comparison*. Ask students to take out the their annotated copies of *Argument 1A: Maintaining Speed Limits* and *Argument 2A: Lowering Speed Limits*. Follow the prompts on the slide as a class:

- *Read through the questions in the first column of the Societal-Impacts Argument Comparison handout.*
- *Read the information filled in for argument #1 and find where these ideas are presented on the Argument 1A: Maintaining Speed Limits handout.*

Create space for students to suggest any additions to the first column of the *Societal-Impacts Argument Comparison*.

ADDITIONAL GUIDANCE

As students work through this second part of the argument comparison, they may need support in understanding the questions in addition to the prefilled example responses. Use the following guidance to help build their understanding. It could also be helpful to remind students that we are considering a "should we" question.

What seems important to the author that could also be guiding their choices? What tradeoffs are being made?

- Explain to students that everyone has values. Each person and group of people have different things that are important to them, their community, their families, and their lives.

✱ SUPPORTING STUDENTS IN ENGAGING IN ARGUMENT FROM EVIDENCE

During this discussion, students are engaging with many aspects of SEP 7: *engaging in argument from evidence*. In addition to the element included in the assessment guidance, the questions at the end of this tool focus on SEP 7.4: Construct, use, and/or present an oral and written argument or counter-arguments based on data and evidence.

During the last two questions, students review the merits of each design or argument. In that process, students are constructing and using written and/or oral arguments and/or counter-arguments based on the data, evidence, and societal influences to determine which design or argument has the most merit.

- This question is asking students to consider what the author might be placing value on to make this decision, because their values have guided their decision-making process. By considering the values of others, we can consider the reasoning behind their perspective.
- Explain that by considering their perspective, we can also determine what tradeoffs they have thought were important in their decision and why they might have selected a specific tradeoff over another.

What constraints might exist in our community that would make it hard to accept this argument?

- Explain to students that even though something may sound great from a scientific standpoint, it might not work due to limitations in the community or environment. We need to consider those here.
- Encourage students to think about constraints specific to their communities.

How would accepting this argument affect you and others around you, both human and not human? For example, is one group's safety being prioritized, or are there others being put more at risk if this argument is accepted?

- Direct students to look at the last column of their *Engineering Progress Tracker* for ideas. In those columns, students have considered constraints that might impact the implementation of designs and their effects on humans and nonhumans.
- Ask students to consider everyone, and everything, around them in their environment for this question.

What are the long-term effects of accepting this argument?

- This is a space to consider the impacts on society and environment, specifically. This space is to think about the consequences (and cascading effects of those consequences) if this argument is adopted or the solution is implemented over time.

These prompts were adapted from the Learning in Places Collaborative. (2022). *Framework: Complex Socio-Ecological Systems*. Bothell, Seattle, WA, & Evanston, IL: Learning in Places.

 Display **slide Y**. Ask students to complete the second column of the *Societal-Impacts Argument Comparison* in pairs. Give them about 5 minutes to complete this task. Then ask students to share their ideas and cite specific parts of the text to support their answer. Use *Argument Comparison Keys* as a guide.

Prompt students to write on their handout as the class copy is being completed. It is OK if they bring up additional ideas for each box, as students with different lived experiences may think of additional or different societal impacts, depending upon their context. Record these additional ideas as long as they fit with the prompt being used.

Consider both science and societal ideas in argument comparison. Display **slide Z**. Orient students to the prompts on page 2 of *Societal-Impacts Argument Comparison* and give them a couple minutes to answer the prompts individually. Then organize students into groups of 4 and give the groups about 4 minutes to share their ideas and discuss the prompts. Then take about 4 minutes to discuss as a class.

Students will likely have a range of ideas and determinations for these questions. Allow all responses, but ask all students to elaborate on their reasoning. Focus on any conflicts between science and societal perspectives. ✱

After discussing, give students time to add words, such as *tradeoff* or *limitation*, to their Personal Glossary.

Collect *Societal-Impacts Argument Comparison* to provide individual feedback.

ASSESSMENT OPPORTUNITY

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

- Compare and evaluate written arguments (SEP: 7.1) based on tradeoffs, criteria, and constraints that the author has made about speed limits. (DCI: ETS1.B.1)
- Identify possibly unequal effects of accepting the arguments on themselves and others in their community. (CCC: 2.4)
- Identify how these factors influence their thinking about the merits of competing arguments.

See the *Argument Comparison Keys* for example student responses.

What to do: During the discussion, If students are not identifying information for each box, prompt them to refer back to the readings and look for any differences in ideas between the readings and consider how these differences might influence the completion of the boxes.

When reviewing individual work, provide comments on where students could strengthen their answers by adding more details or being specific about connections to the reading. Next lesson, students will be engaging in this activity again with other arguments. Return the written feedback to students before you do this activity.

Building toward: 12.A.2 Evaluate and compare competing arguments related to policy decisions to change speed limits within driving systems based on scientific knowledge and principles, prioritized criteria, unequal effects, limitations (e.g., tradeoffs), constraints, and societal and ethical impacts. (SEP: 7.1; CCC: 2.4; DCI: ETS1.B.1)

10 · UPDATE THE DRIVING QUESTION BOARD

5 min

MATERIALS: 3x3 sticky notes, permanent marker, Driving Question Board

Add questions to the DQB. Distribute sticky notes and permanent markers. Project **slide AA**. Pause and allow students to add to the DQB any new questions they have. Ask them to quickly share their questions out loud as they post them and to add them to the relevant question clusters. Point out that we have a lot of questions about implementation of design and policy for vehicle safety.

11 · COMPLETE THE ELECTRONIC EXIT TICKET

15 min

MATERIALS: computer with access to https://docs.google.com/forms/d/11qXSTaY2m8I1PUbaYR17yqZVvlVEfS1TOsxI4VTFVOY/copy

Complete an Electronic Exit Ticket. Display **slide BB**. Have students complete https://docs.google.com/forms/d/11qXSTaY2m8I1PUbaYR17yqZVvlVEfS1TOsxI4VTFVOY/copy with the remaining time in class.

ALTERNATE ACTIVITY

If students are curious about some of the topics that came up in this lesson, use *Extension Opportunities* from Lesson 8 to point them to additional resources. Consider forecasting the Community Design Solution project in Lesson 14 and asking students to do additional research at the library or online that can be used to inform those design solutions.

Additional Lesson 12 Teacher Guidance

SUPPORTING STUDENTS IN MAKING CONNECTIONS IN ELA

CCSS.ELA-LITERACY.RI.11-12.1 Cite strong and thorough textual evidence to support analysis of what the text says explicitly as well as inferences drawn from the text, including determining where the text leaves matters uncertain.

Students read competing arguments and then use textual evidence to analyze the claims, priorities, tradeoffs, and connections to science ideas within each argument. They then use these analyses to evaluate which argument has more merit.

CCSS.ELA-LITERACY.WHST.9-10.1.A Introduce precise claim(s), distinguish the claim(s) from alternate or opposing claims, and create an organization that establishes clear relationships among the claim(s), counterclaims, reasons, and evidence.

Students engage in comparison and evaluation of two arguments and identify the claims of each argument. They make a claim of which argument has the most merit based on evidence they have extracted from the text and organized within the provided comparison tables.