Lesson 14: What can we do to make driving safer for everyone in our community?

Previous Lesson *We used the Argument Comparison Tool to compare arguments relevant to our community. We surveyed community members about local problems with our transportation system.*

This Lesson

Putting Pieces Together

3 days

We identify driving-related problems we care about, then consider the scope of these problems and related physics models to narrow down to a single problem per group. We consider cause and effect to prioritize criteria, then get peer feedback on how to model this system. We then identify reasonable approximations and develop our proposal in a format we choose.

Next Lesson *We will take an end-of-unit assessment. We will revisit the DQB and determine what questions we can now answer. We will reflect on and document the most important things learned in our unit.*

BUILDING TOWARD NGSS

ETS2.B.3, ETS1.C.1

What students will do

14.A Define a design problem within a vehicle-related system by analyzing how transportation technologies impact society to a level that requires attention or mitigation, considering the scale, proportion, and quantity at which the problem is significant. (SEP 1.8; CCC 3.1; ETS2.B.3)

14.B Design and/or refine a solution to a problem related to vehicle safety, considering cause-effect relationships suggested or predicted by smaller-scale mechanisms within the system and prioritizing certain criteria over others to optimize the focus. (SEP 6.5; CCC 2.2; ETS1.C.1)

14.C Use reasonable assumptions or approximations to develop a mathematical model to generate data to predict behavior of a design solution, analyze a system or support an explanation, and meet prioritized criteria. (SEP 2.6; CCC 4.4; ETS1.C.1)

What students will figure out

- We can impact local change by offering evidence-based solutions to specific, solvable problems.
- We can analyze problems by considering the scope of the effect they have on people or things we care about.
- Identifying cause-effect factors within a system can help us identify places to target solutions and prioritize specific criteria to optimize these solutions.
- We can use approximated values and reasonable assumptions in our physics models to support a case for why a problem exists or how a solution can make it safer.

Lesson 14 • Learning Plan Snapshot

Part	Duration		Summary	Slide	Materials
1	3 min		**NAVIGATE** Prompt students to discuss examples of real-world problems.	A	*Community Interview*
2	12 min		**BRAINSTORM REAL-WORLD PROBLEMS** Consider in groups examples of possible real-world problems. Begin thinking about the Design Challenge project.	B	*Design Challenge Organizer*, *Case Study #1: Electric Cars*, *Case Study #2: Our Crumple Zone Designs*, *Case Study #3: Self-Driving Car Ethics*
3	22 min		**NARROW TO ONE SPECIFIC PROBLEM AND GET FEEDBACK** Choose one problem in each group to focus on for their project.	C-E	*Design Challenge Organizer*
4	5 min		**SHARE PEER FEEDBACK WITH TEAMS, CONSIDER SCALE, PROPORTION, AND QUANTITY** Incorporate peer feedback into each group's design problem.	F	*Design Challenge Organizer*
5	3 min		**NAVIGATE** Contrast defining problems with developing solutions.	G	*Design Challenge Organizer*
					End of day 1
6	7 min		**TAKE STOCK** Take stock of where the class has been by revisiting the graphs from Lesson 1. Surface the idea that multiple complex factors are at play in both of these graphs.	H-I	*Design Challenge Organizer*, computer with access to https://docs.google.com/spreadsheets/d/1EqONf6yEYqLFZZn4LUcmzFQeJNATscIE9rWCmN-xNyO/copy, computer with access to https://s3.amazonaws.com/p.3simulation/collisions/sandbox.html (optional)
7	8 min		**EXAMINE EXAMPLES OF SOLUTIONS** Look through examples of presentations. Consider what the problem and solution are and what criteria the designers may have prioritized.	J-K	2 copies of *Final Product Example Summary*, https://docs.google.com/presentation/d/1oOonZVXDajELVudwtdUuDT97C5H8xP

				NC5amy8bFH320/copy, chart paper, chart paper markers
8	10 min	**CONSIDER CAUSE AND EFFECT TO PRIORITIZE DESIGN CRITERIA** Consider how cause-effect details within the system might impact the safety of people. Use these considerations to help prioritize criteria.	L	*Design Challenge Organizer*, 2 copies of *Final Product Example Summary*
9	10 min	**CONSIDER CRITERIA TO DESIGN POSSIBLE SOLUTIONS** Consider the prioritized criteria students identified to develop solutions to the problem they've chosen.	M	*Design Challenge Organizer*
10	5 min	**GET PEER FEEDBACK ON SOLUTIONS** Share ideas for solutions in partners with a student who isn't in their project group and get feedback on how to proceed.	N	*Design Challenge Organizer*, posters developed throughout the unit (see Materials Preparation)
11	5 min	**SHARE PEER FEEDBACK WITH TEAM AND NAVIGATE** Share peer feedback in project groups and jot down notes on how to connect the problem or solution to physics models.	O-P	*Design Challenge Organizer*, posters developed throughout the unit (see Materials Preparation)
				End of day 2
12	6 min	**NAVIGATION** Consider the validity of values in a model and reflect on an example of a computational model about airbags.	Q-R	*Physics Models Used in Design Solutions* (optional)
13	18 min	**APPLY PHYSICS MODELS TO OUR PROBLEMS OR SOLUTIONS** Consider which physics models help with understanding details about a problem and/or solution and choose reasonable values that make the modeling reliable.	S-T	*Design Challenge Organizer*, computer with access to https://s3.amazonaws.com/p.3simulation/collisions/sandbox.html (optional), posters developed throughout the unit (see Materials Preparation)
14	18 min	**COMPILE WORK INTO A FINAL PRODUCT** Choose a Final Product format--slide deck, pamphlet, infographic, etc.--then into this format teams compile their best work.	U-V	*Design Challenge Organizer*, *Final Product Example Summary*, https://docs.google.com/presentation/d/1

				oOonZVXDajELVudwtdUuDT97C5H8xPNC5amy8bFH32O/copy
15	3 min	**NAVIGATE** Forecast the assessment opportunity in the next lesson.	W	

End of day 3

Lesson 14 • Materials List

	per student	per group	per class
Lesson materials	• *Design Challenge Organizer*	• *Community Interview* • *Case Study #1: Electric Cars* • *Case Study #2: Our Crumple Zone Designs* • *Case Study #3: Self-Driving Car Ethics* • computer with access to https://docs.google.com/spreadsheets/d/1EqONf6yEYqLFZZn4LUcmzFQeJNATscIE9rWCmN-xNyO/copy • computer with access to https://s3.amazonaws.com/p.3simulation/collisions/sandbox.html (optional) • 2 copies of *Final Product Example Summary* • https://docs.google.com/presentation/d/1oOonZVXDajELVudwtdUuDT97C5H8xPNC5amy8bFH32O/copy • *Physics Models Used in Design Solutions* (optional) • *Final Product Example Summary*	• chart paper • chart paper markers • posters developed throughout the unit (see Materials Preparation) • https://docs.google.com/presentation/d/1oOonZVXDajELVudwtdUuDT97C5H8xPNC5amy8bFH32O/copy

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.

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

If possible, make sure the following posters are clearly visible in the room:

- Puzzling Patterns from Lesson 1
- Force and Motion Relationships from Lessons 6 and 9
- Momentum Relationships from Lesson 6
- Crumple Zone Length from Lesson 11
- Gotta-Have-It Checklist from Lesson 12

Make a copy of the *Design Challenge Organizer* for individual students either on paper or digitally. This organizer is designed to help students make incremental progress toward a presentation in a format of their choosing. It is likely that each student's individual copy of the *Design Challenge Organizer* is the best record of their individual understanding for project assessment purposes.

However, in order to make it feasible for teachers to give frequent feedback on this work, it may only be possible to collect and give feedback on one copy per group of this work at the end of each class period. While the student-facing materials and slides do not reference this, if you plan to use work on the *Design Challenge Organizer* as part of individual summative project work, make sure to modify the slides to clarify this to students. For example, you might clarify to students at the beginning of each period that the copy to be collected for each group will be randomly selected, to encourage group members to hold one another accountable for individual work. Alternatively, you could alter the slides to prompt all students to hand in their work, and then focus on giving feedback on just one sample per group.

At a minimum, plan to provide targeted feedback to each group as described in *Design Challenge Organizer Key*. In some cases, this feedback might involve copies of resources (such as *Case Study #1: Electric Cars*, *Case Study #2: Our Crumple Zone Designs*, and *Case Study #3: Self-Driving Car Ethics*). Rather than giving these materials to all groups, provide them as scaffolded tools for groups or individuals that need them.

If students found *Argument Comparison Tool* to be a useful tool in Lesson 13, *Scaffolded Argument Tool* has a similar structure, with sentence starters to aid students in applying these ideas to a design problem or solution setting. If some students have to complete the project work independently or if a group has less time to spend on the project than they will need, scaffolding the project thinking with the *Scaffolded Argument Tool* may be the right choice.

Your experience with formative assessment work done by your students may suggest that certain individuals will have trouble understanding the work that their group does prioritizing criteria or modeling physics related to their solutions. If you are not collecting and assessing all students' individual work, do not assume that these students have mastered the project objective. Instead, use the class time when groups are working to inspect the written work of these students and verbally check for understanding.

For example, you might choose to take notes for yourself on specific students' progress, in order to plan targeted interventions, or consider extension work for students who have mastered the basic content in the project. You might take additional class time to give some students a chance to work on polishing their Final Product artifacts (presentation, PSA, etc.) while individuals from all groups who haven't mastered specific objectives work with you and one another to deepen their understanding in the *Design Challenge Organizer*.

Lesson 14 • Where We Are Going and NOT Going

Where We Are Going

This lesson is designed to coherently build and assess ideas related to the following disciplinary core ideas:

- **ETS1.A.1: Defining and Delimiting Engineering Problems.** Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. (HS-ETS1-1)
- **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)

Since not all the models built in the unit will be relevant to each problem or design solution, consider this project a putting-the-pieces-together lesson for specific applications of one specific model. Students have the chance to evaluate where they have been, what models they have built, and how they can use those models to make decisions. There is no single right way for students to make these decisions. What is important is that they know how to justify their decisions using a combination of engineering ideas about criteria, constraints, and trade-offs and science ideas about motion, force, and momentum.

This lesson also includes a connection to the Nature of Science, as outlined in Appendix H of the NGSS, as part of the High School criteria for the category: **Science Addresses Questions about the Natural and Material World**.

- Not all questions can be answered by science.
- Science and technology may raise ethical issues for which science, by itself, does not provide answers and solutions.
- Scientific 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.
- Many decisions are **not** made using science alone, but rely on social and cultural contexts to resolve issues.

Where We Are NOT Going

It is not a goal of this project to tie together all models built in the unit. While some problems or design solutions may connect to more than one core physics model, the focus of the project is on applying one model to a specific real-world application, not tying together multiple models.

As stated in the assessment guidance for 14.C.1, there may be a tension between a problem or solution that a group of students feels ownership of and cares about deeply versus a problem or solution that uses physics models most effectively. Consider priorities for your own class and your student population. It may not be the case that relevant, accurate physics modeling is more important. If you find yourself having to “choose” between student ownership and physics content understanding, consider the long-term benefit to students’ science literacy of pursuing a solution they feel passionate about.

LEARNING PLAN for LESSON 14

1 · NAVIGATE

3 min

MATERIALS: *Community Interview*

Share ideas about what can make driving less safe. Present **slide A**. Say, *We've learned a lot about why driving can make the world more dangerous. Now let's see if we can brainstorm some concrete solutions that will make driving safer in our community***.** Then read the prompt on the slide:

- *What are examples of locations, activities, or policies that put people, animals, or the environment at risk because of cars or driving?*

Tell students to get out *Community Interview* or *Engineering Progress Tracker* and consider with a partner specific examples in our community where people are put at risk because of cars or driving.

After about a minute with a partner, ask students to share with the class. Listen for responses such as the following:

- A certain intersection near school is busy or dangerous.
- Speed limits are too high or too low in specific places.
- Not enough people have (specific safety features) installed.
- Heavier vehicles (i.e., farm equipment, trucks) are more dangerous for everyone except the people inside that vehicle.
- Wildlife crossing roads between green spaces.
- Neighborhoods that are designed for cars to move through quickly and that have little pedestrian infrastructure.
- Parks and playgrounds near freeways and heavy exhaust.

2 · BRAINSTORM REAL-WORLD PROBLEMS

12 min

MATERIALS: *Design Challenge Organizer*, *Case Study #1: Electric Cars*, *Case Study #2: Our Crumple Zone Designs*, *Case Study #3: Self-Driving Car Ethics*

Communicate that the goal of the project is to make our community safer. Reiterate some of the ideas students had in the earlier conversation and clarify that these are examples of places to focus our solutions. Then state that we could use a *Design Challenge Organizer* to consider how we can make our community safer. Pass out a copy of the *Design Challenge Organizer* to each student and emphasize to students that to begin this process, we're going to think broadly about a lot of possible problems, then gradually narrow our focus.

Brainstorm possible design problems related to safety of cars or driving. Present **slide B**. Put students in groups of 3-5, aiming for 6-8 groups total. Prompt students to use the *Design Challenge Organizer* to brainstorm possible ideas for what they might focus on for their

Design Challenge project. Say, *As you talk with your group, share your own new ideas along with ideas from Community Interview or Engineering Progress Tracker. Jot down notes in step 1 in the Design Challenge Organizer*.

As you circulate around the room, pay attention to which ideas seem like they could be fruitful to pursue further. In particular, try to direct groups toward design problems that

- are of a realistic scale (i.e., advocating for a new stop sign or bike lane, recruiting volunteers to escort students in an intersection, creating a sign to warn drivers about crossing animals, speaking at a city council meeting, letter writing campaign to congress, public information campaign for peers).
- can be connected in some way to one of our three categories of physics models:

i. velocity graphs, reaction distance, braking distance;
ii. force and changes in motion while braking, crumpling, or stopping; or
iii. conservation of momentum.

If you notice a problem that seems pertinent to one of these three models, point this out to the group who recorded it. Say, *I like how this problem connects so closely to our velocity graph/force and changes in motion/conservation of momentum models. Did you notice that connection also?*

Based on your background knowledge about your students, you may already have a hunch about what design problem a specific group might want to take on. Try to find a balance between giving students "just in time" suggestions to help push their thinking forward (for example, by giving them a copy of *Case Study #1: Electric Cars*, *Case Study #2: Our Crumple Zone Designs*, or *Case Study #3: Self-Driving Car Ethics*) and allowing students a chance to own the Design Challenge process themselves. This balance will vary from group to group. This balance will be similarly important if none of the design problems a group has identified seem connected to physics models. Depending on your student population and teaching environment, there may be value in a group taking on a design problem they feel strongly about, even if it doesn't connect clearly to physics models.

In particular, a project grounded in *Case Study #2: Our Crumple Zone Designs* will be quite a bit different from other projects, as it will involve more hands-on design work, very similar to what all students did in Lesson 10. If you know that certain students would value the chance to spend more time improving their crumple zone design, make sure to inform them that this is a project option, as they otherwise may not realize that this "hands-on" option is possible.

3 · NARROW TO ONE SPECIFIC PROBLEM AND GET FEEDBACK

22 min

MATERIALS: *Design Challenge Organizer*

Narrow focus to one specific, solvable design problem. Present **slide C**. Say, *It looks like we have identified many, many possible problems we could choose to prioritize, but if we're actually going to make progress we need to narrow our focus. Let's try doing this in two ways--first, look with your group at question 2 and choose which problems our physics models will help us think through, then use question 3 to decide which of those problems your group thinks is most important.*

If you'd like, give an example of one group that already found this connection, and point this out to the class. Say, *This group identified the problem of ..., and we agreed that it connects to our model of ....*

As students think through question 2, continue to circulate around the room and glance at which problems could be closely connected to our physics models. This is another opportunity to intervene with a case study handout if you notice students having trouble narrowing their focus.

Present **slide D**. Call students' attention to question 3 in the *Design Challenge Organizer*. Point out to students that they now need to, with their group, narrow down to a single design problem that they will focus on trying to solve.

Point out that part of prioritizing will be to think through the scale, proportion, and quantity at which the problem occurs. Say, *If your group disagrees about which problem is more important or impactful, it may help to discuss the questions in a and b for a couple different problems. Some problems will clearly seem more widespread or more frequent, while others may seem more impactful because they're so specific--like a specific intersection near our school. It's up to you and your group how you consider scale, proportion, and quantity to help you define your design problem.*

Once they've narrowed down their problem, they can describe it using words or drawings. ✱

ASSESSMENT OPPORTUNITY

14.A.1 What to look/listen for in the moment: Look for student work in question 3 of the *Design Challenge Organizer* to

- select a transportation-related design problem that includes social, technical, and/or environmental considerations and is relevant at a scale, proportion, and quantity that matters to people or things students care about. (SEP 1.8; CCC 3.1; ETS2.B.3)

What to do: As students are working on questions 1-3, circulate around the room to monitor who is making progress. Look out for groups that are having trouble connecting to physics ideas or identifying specific problems in detail. If a group seems truly stuck, offer them the option of looking over some optional case studies, such as *Case Study #1: Electric Cars*, *Case Study #2: Our Crumple Zone Designs*, or *Case Study #3: Self-Driving Car Ethics*, that could provide them with some fruitful ideas. Use the example responses and rubric in *Design Challenge Organizer Key* to guide your verbal feedback.

✱ ATTENDING TO EQUITY

Universal Design for Learning: If you notice that a group is having trouble putting ideas about their problem into words, encourage them to represent their ideas with pictures instead. This may help students get ideas down so that they can move forward thinking through other parts of the project. They will have chances to write down their ideas in words later, once these ideas are more fully formed.

At this point in class, **prioritize supporting each group to find a design problem that (a) matters to the team and (b) seems possible to solve with ideas related to our physics models**. If you notice that students are struggling to narrow the focus of their design problem in question 3, prompt them to verbally share details about the scope or quantity at which the problem occurs in order to define a design problem that requires attention or mitigation.

Say, *Take one of the problems you identified in question 1 or 2. Where and when in our community does this problem occur? Who does it affect, and how? Now let's contrast that answer with a different problem. Where and when does that second problem occur? Thinking about the two problems with this in mind, which problem seems higher priority to focus on?*

At the end of class, collect at least one sample response for question 3 from each group, then give written feedback on this work before the next class as described in *Design Challenge Organizer Key*.

Building toward: 14.A.1 Define a design problem within a vehicle-related system by analyzing how transportation technologies impact society to a level that requires attention or mitigation, considering the scale, proportion, and quantity at which the problem is significant. (SEP 1.8, CCC 3.1, ETS2.B.3)

Introduce the TAG protocol for peer feedback. After 15 minutes of group work, present **slide E**. Tell students that they will have a "lightning round" of peer feedback to share their work and guide their thinking going forward. Explain how to give TAG feedback: Tell something you like, Ask a question, Give a suggestion.

Give students about 1 minute to give and get feedback, then trade roles with their partner. If students have time, they can repeat the process with a second partner. It is not important that each individual gets the same amount of feedback, but every student should have a chance to share and get feedback at least once. After about 5 total minutes of peer feedback, ask students to return to their original project group.

4 · SHARE PEER FEEDBACK WITH TEAMS, CONSIDER SCALE, PROPORTION, AND QUANTITY

5 min

MATERIALS: *Design Challenge Organizer*

Record ideas from peer feedback in small groups. After students have regrouped, present **slide F**. Tell students to share with their group what they learned through peer feedback. Communicate to students that they should write notes from peer feedback on at least one team member's copy of question 3.

Say, *Be ready to hand in one group member's copy of the Design Challenge Organizer at the end of class. I'll read through your progress on question 3 and give you my thoughts. If I have any resources or evidence that could be useful to you in coming up with solutions, I'll suggest those to you in our next class.*

5 · NAVIGATE

3 min

MATERIALS: *Design Challenge Organizer*

Prompt students to share thoughts on "defining a design problem" versus "developing a solution". Present **slide G**. Ask students to share their thoughts on what was interesting or challenging about the work they did today deciding on a design problem. Ask students to consider what might be interesting or challenging about developing solutions.

Accept all responses, such as the following:

- We had trouble finding something specific.
- We all agreed that our solution could actually save lives.
- It's clear how the physics on the __ poster will help us show why the problem matters.
- We had trouble connecting to physics ideas so far.
- Developing solutions can be exciting because it feels like we're saving lives.
- It's going to be challenging to solve this problem; we don't have any solutions yet.

Emphasize that starting next class students will be focusing on developing solutions. Try to get a sense of the general mood in the classroom from students' responses to the questions on **slide G** and help students see the opportunity for optimism as we go into developing solutions.

For example, if students' mood around focusing on problems is generally optimistic, say, *It sounds like we're feeling good about taking on some important problems in our community and making driving and cars safer for everyone. I'm so excited to see what you come up with when we start designing solutions!*

Alternatively, if students seem generally pessimistic about the opportunity to make a difference with the problems they've identified, acknowledge this challenge but focus on building students' confidence. Say, *I'm very impressed that you were able to push through this challenging moment--well done. Part of the design process always involves coming face to face with real problems, and this can be exhausting. But it's also useful to take some time away from this state of mind to approach solutions with a fresh perspective.*

Collect one copy of the *Design Challenge Organizer* from each group in order to give written feedback according to the assessment guidance above and in *Design Challenge Organizer Key*.

End of day 1

6 · TAKE STOCK

7 min

MATERIALS: *Design Challenge Organizer*, computer with access to https://docs.google.com/spreadsheets/d/1EqONf6yEYqLFZZn4LUcmzFQeJNATscIE9rWCmN-xNy0/copy, computer with access to https://s3.amazonaws.com/p.3simulation/collisions/sandbox.html (optional)

Take stock of where we have been by revisiting the graphs from Lesson 1. Present **slide H**. Take a moment to quickly point out the trends that the class identified. Then give students about two minutes to turn and talk about the prompt on the slide and the accompanying graphs: *Can we apply our ideas about safety systems and other factors to explain these data trends?*

After a few minutes, elicit ideas from students. Look for ideas about safety features mitigating risky driving behavior such as faster speeds, distraction, etc. Remind students that in Lesson 7 our data suggested that injuries and deaths should be even higher than they are.

Say, *As you go forward coming up with solutions to problems that still exist, consider that very small changes on these graphs can have huge impacts on people's lives.*

Navigate back into developing design solutions. Present **slide I** and return any copies of the *Design Challenge Organizer* to students, with feedback and suggestions written. Say, *Last time, we identified some problems that still exist in our communities. Today we'll get to think more deeply about how to solve those problems. Look back at question 3 in your copy of the Design Challenge Organizer, and let's think more about how we can use our physics knowledge to help solve these problems.*

Say, *Review your work and feedback in the Design Challenge Organizer. Pay special attention to any resources I proposed that you use and potential connections to our physics models and science ideas.*

If your students have easy access to a computer, say, *There are a lot of useful resources online about problems with driving safety, potential solutions, and even physics to explain how these solutions work. Look through the Key Words Database for sources that could help you make progress today.*

The link to the Key Words Database is available here:
https://docs.google.com/spreadsheets/d/1EqONf6yEYqLFZZn4LUcmzFQeJNATscIE9rWCmN-xNy0/copy

If students' project ideas could benefit from experimenting within the Vehicle Collision Simulator, consider providing them with the sandbox version of the simulation (https://s3.amazonaws.com/p.3simulation/collisions/sandbox.html).

Give students 4 minutes to review feedback in groups and to locate or browse through any resources you have provided.

7 · EXAMINE EXAMPLES OF SOLUTIONS

8 min

MATERIALS: 2 copies of *Final Product Example Summary*, https://docs.google.com/presentation/d/1oOonZVXDajELVudwtdUuDT97C5H8xPNC5amy8bFH320/copy, chart paper, chart paper markers

Ask students to look through a few examples of problems and solutions. Present **slide J**. Give students a paper copy of *Final Product Example Summary*. Ask students to share what they notice in these examples. Say, *Before we develop our own solutions, let's look through a few examples of finished products. What do you notice? What is the problem? What is the solution? What criteria did the designers of this solution prioritize?*

You may choose to have a few copies of the https://docs.google.com/presentation/d/1oOonZVXDajELVudwtdUuDT97C5H8xPNC5amy8bFH320/copy printed to give students a chance to think through what their Final Product presentations might look like. If you print a few copies of the exemplars, hand out *Final Product Example Summary* first to give students enough time to think through the summary without focusing on details like images and layout.

Look for answers such as the following:

Problems

- I notice that the problems seem very specific.
- There's an intersection that's dangerous for people on bikes.
- There are too many private vehicles clogging up our roads.

Solutions

- Some problems have two solutions, and some have just one.
- I notice that some of these solutions could be hard to make happen--some people will be annoyed.
- One solution to lifted trucks is to ban them on highways.
- I'm not 100% sure that these solutions would work, but they might.

Criteria

- The designers of the first solution prioritized the safety of cyclists.
- The designers of the airbag solution prioritized people who don't have enough money to buy a car with an airbag.

After sharing a few answers, try to generalize students' comments in a positive light to direct their focus toward solutions that address specific criteria. Say, *It sounds like we have some questions about whether the solutions would work for everyone. Know that even the examples of good work are going to raise those types of questions.*

Brainstorm possible types of solutions for our community. Present **slide K** and read the prompt on the slide. Say, *Before we work on solutions to your specific problems, let's brainstorm some general ideas of solutions that might have an impact. What ideas do you have about what we might do as drivers, passengers, and residents that could make driving safer for people in our community by raising awareness, changing driver behavior, or making our driving environment safer?*

Give students a full minute to discuss possible ideas with a partner, then ask students to share their ideas. As students share, capture their ideas on a piece of chart paper labeled "Possible Solutions for Our Community".

Look for ideas about policy changes or campaigns to change driver behavior, making safer vehicles easier to acquire, or infrastructure changes to specific locations, such as the following:

- Public service campaign, posters, or a phone call campaign to raise awareness
    - Don't drive distracted or drunk.
    - Take public transportation more, or ride bikes more.
    - Drive slower in specific places.
- Make safer cars more available
    - Give away money or provide tax breaks.
    - Pass laws to require cars to have specific safety features.
- Change specific intersections or roads
    - Install more bike paths.
    - Install more traffic lights.
    - Install pedestrian bridges.
    - Post speed limits or install speed humps on specific roads.

8 · CONSIDER CAUSE AND EFFECT TO PRIORITIZE DESIGN CRITERIA

10 min

MATERIALS: *Design Challenge Organizer*, 2 copies of *Final Product Example Summary*

Prompt students to consider cause-effect details that could impact their design problem. Present **slide L** and ask students to find step 3, question 4 in the *Design Challenge Organizer*. Frame the prompts on the slide and question 4 as a way to identify factors in the system where we can change the outcome. Say, *If we think about cause and effect within the system, then it can be much easier to identify places in the system where we can fix the problem we've identified. For example, if accidents on a specific road are caused by people driving too fast, then installing speed humps to reduce speed is likely to reduce accidents also*. Alternatively, you can frame these prompts with a question by asking, *Why might cause-effect relationships be a useful way to identify places where solutions could help improve our design problem?*

Look for answers such as these:

- Cause and effect means that a specific factor causes something else to happen or not happen.
- If we know what causes the problem, then it's easier to know how to fix it.

Point out to students that question 4b in the *Design Challenge Organizer* will require them to make some choices, just like we saw in the examples. Say, *Notice that question 4b asks you to prioritize specific criteria: "What do you want the solution to accomplish?" Why do you think it's important to prioritize criteria before identifying a solution?* ✱

Look for answers such as these:

- No solution is ever going to satisfy everyone at once.
- We should think about who or what we think is most important, then our solution can focus on those things.

Provide students with time in groups to write down their answers to questions 4a and 4b.

ASSESSMENT OPPORTUNITY	**14.A.2 What to look/listen for in the moment:** Look for student work in question 4b of the *Design Challenge Organizer* to • describe criteria and trade-offs related to a system with interacting components--the relevant transportation technology problem they chose on day 1. (SEP 1.8; ETS2.B.3) **What to do:** Circulate from group to group, looking at students' written answers to question 4b and asking groups what criteria they have prioritized. If it looks like students are having trouble narrowing their focus and prioritizing criteria, direct their attention to the examples on *Final Product Example Summary*. Use questioning to help students see that these examples have chosen specific aspects of the problem to solve. Say, *Study the "Criteria" column for the example about airbags. Whose safety does this solution prioritize? What about the cyclist safety example? Who and where does this solution prioritize?*

✱ SUPPORTING STUDENTS IN ENGAGING IN CONSTRUCTING EXPLANATIONS AND DESIGNING SOLUTIONS

Prioritizing Criteria when Designing Solutions
When designing solutions, we should encourage students to consider what specific criteria they want to prioritize. No solution will satisfy all possible criteria--a good solution weighs various possible criteria to make an informed choice about which is most important.

If a group is still having trouble narrowing their focus, they may need more specific guidance or resources. Refer to *Design Challenge Organizer Key* for more detailed guidance on how to give targeted feedback and consider giving them explicit instruction on cause-effect details related to the system where their chosen design problem takes place.

Building toward: 14.A.2 Define a design problem within a vehicle-related system by analyzing how transportation technologies impact society to a level that requires attention or mitigation, considering the scale and quantity at which the problem is significant. (SEP 1.8, CCC 3.1, ETS2.B.3)

9 · CONSIDER CRITERIA TO DESIGN POSSIBLE SOLUTIONS

10 min

MATERIALS: *Design Challenge Organizer*

Prompt students to develop solutions that address their chosen criteria. Present **slide M** and direct students' attention to question 5 on the *Design Challenge Organizer*. Say, *Now that you have chosen criteria to optimize the focus of your solution, it's time to actually develop these solutions. You've probably suggested ideas to one another at some point before now, but take a moment to discuss as a team what possible solutions could make sense. Then, once you've decided on one or two solutions, write or draw these solutions in question 5 so it's easy to get feedback on your idea from me and from other students.*

ASSESSMENT OPPORTUNITY

14.B What to look/listen for in the moment: Look for student work in the *Design Challenge Organizer* questions 4-5 to

- suggest and predict cause-effect mechanisms relevant to the criteria of the problems they've identified and potential solutions and prioritize what to focus on, since some causes will be more realistic to affect than others. (CCC 2.2, ETS1.C.1)
- prioritize specific criteria in their solutions, so look for them to recognize that their solution will only address some specific parts of the problem they identified. (SEP 6.5, ETS1.C.1)

What to do: Circulate from group to group, looking at students' written answers to question 4b and asking groups what solutions they have come up with. If some groups are struggling for ideas, direct their attention to the notes on chart paper titled "Possible Solutions for Our Community" made earlier in the class period. Ask the group, *Do you think you'll focus more on a public service campaign or law, or making safer vehicles more* *available, or changing the driving conditions in a specific location? Which of these seems more appropriate for your design problem and criteria?*

Ask students direct questions about cause-and-effect factors to help them optimize the focus of their design solution. Say, *What do you think is causing __ ? What might you suggest to help make that safer?*

As students gravitate toward specific solutions, remind them of their chosen criteria. Ask, *What were the criteria you chose in question 4b? Can you clarify to me how this solution helps address these criteria?*

Refer to *Design Challenge Organizer Key* for detailed guidance on how to give targeted feedback.

Building toward: 14.B Design and/or refine a solution to a problem related to vehicle safety, considering what is known about cause-effect relationships in smaller-scale mechanisms within the system and prioritizing certain criteria over others to optimize the focus. (SEP 6.5, CCC 2.2, ETS1.C.1)

10 · GET PEER FEEDBACK ON SOLUTIONS

5 min

MATERIALS: *Design Challenge Organizer*, posters developed throughout the unit (see Materials Preparation)

Reintroduce the TAG protocol for peer feedback and clarify details for where to give feedback.

The TAG Peer Feedback protocol (Tell something you like, Ask a question, Give a suggestion for improvement) is a very quick way for students to share work with each other and get actionable feedback. In this iteration of using the TAG feedback protocol, the questions and suggestions are directed toward specific project-related objectives, as described on **slide N**.

Present **slide N** and say, *We used this same structure for getting "lightning round" feedback last class, but there are a few differences this time around. When you're giving feedback, try to focus your questions on criteria or trade-offs. When you're giving suggestions, focus on specific physics models.*

Reference the class community agreements and say, *Please remember that we are dealing with topics that may be connected to strong feelings and traumatic experiences.*

Call students' attention to the model posters around the room. Remind them that they thought about this last time in question 2 of the *Design Challenge Organizer*, and they'll need to think about it again in order to complete the work for this project. Say, *This is a good* *opportunity for suggestions because I haven't asked you to think about it in teams yet. We all have different understandings and take-aways from using these physics models, and your TAG feedback partner may have some fresh perspective to help you make progress with this modeling as we complete our work together during next class.*

The rationale for focusing questions and suggestions on specific details is related to students' ownership of their team's project work. Other students will likely have strong opinions about what solutions might work, which criteria to prioritize, or whether certain trade-offs are wise or fair. While this is potentially relevant, emphasizing it may detract from each team's sense of owning their solutions.

Give students about 1 minute to give and get feedback, then trade roles with their partner. If students have time, they can repeat the process with a second partner. It is not important that each individual gets the same amount of feedback, but every student should have a chance to share and get feedback at least once. After about 5 total minutes of peer feedback, ask students to return to their original project groups.

11 · SHARE PEER FEEDBACK WITH TEAM AND NAVIGATE

5 min

MATERIALS: *Design Challenge Organizer*, posters developed throughout the unit (see Materials Preparation)

Prompt students to share peer feedback with their project group and record notes. Present **slide O** and read the prompts on the slide aloud. Say, *What did people like about your solutions? What questions came up about criteria or trade-offs? What suggestions came up about modeling? Your group will be handing this in as a part of your exit ticket, so jot down notes on at least* ***one*** *copy of the Design Challenge Organizer.*

Prompt for specific ideas about physics models. Present **slide P**, and say, *Next time, we'll get deeper into how we can use our physics models to help convince others that our design solutions are valid. For now, make sure you jot down some ideas about this on one copy of the Design Challenge Organizer so I can give you feedback. You can focus on how to model what makes the problem dangerous* ***or*** *how your solution helps make people safer.*

Allow groups to choose which copy of the *Design Challenge Organizer* they hand in to you as their group exit ticket.

ASSESSMENT OPPORTUNITY	**14.C.1 What to look/listen for in the moment:** At this point, students may only have a very rough idea of what sort of modeling will be helpful to them in their project. That's OK, as they will spend much more time on this next class. In the time between day 2 and day 3, look at one copy of each group's *Design Challenge Organizer* for evidence that this group will be able to • identify a useful category of physics models we have developed together in this unit, and note this in question 6.

- target their modeling on these prioritized criteria or relevant details about the solution. (ETS1.C.1)

What to do: If a project group hasn't recorded any useful model ideas in question 6, this could mean that they'll need a lot of support navigating this challenging task. Think through what models might be useful for explaining such a group's problem or solution and consider making specific suggestions to steer them in a useful direction.

In addition, you may choose to provide specific resources on paper or links. Lightly review *Design Challenge Organizer Key* and the Key Words Database (https://docs.google.com/spreadsheets/d/1EqONf6yEYqLFZZn4LUcmzFQeJNATscIE9rWCmN-xNyO/copy) before and during the time you're giving feedback to students, in case some resources stand out as particularly helpful to one group or another. Whether or not you choose to provide specific notes or resources, it may help to record notes to yourself on which groups will likely engage with which physics models. This will make it easier to check for understanding on day 3.

There may be a tension at this point between a problem or solution that a group of students feels ownership of and cares about deeply versus a problem or solution that uses our physics models most effectively. Consider priorities for your own class and your student population. It may not be the case that relevant, accurate physics modeling is more important. If you find yourself having to choose between student ownership and physics content understanding, consider the long-term benefit to students' science literacy of pursuing a solution they feel passionate about.

Refer to *Design Challenge Organizer Key* for detailed guidance on how to give targeted feedback.

Building toward: 14.C.1 Use reasonable assumptions or approximations to develop a mathematical model to generate data to predict behavior of a design solution, analyze a system or support an explanation, and meet prioritized criteria. (SEP 2.6, CCC 4.4, ETS1.C.1)

End of day 2

12 · NAVIGATION

6 min

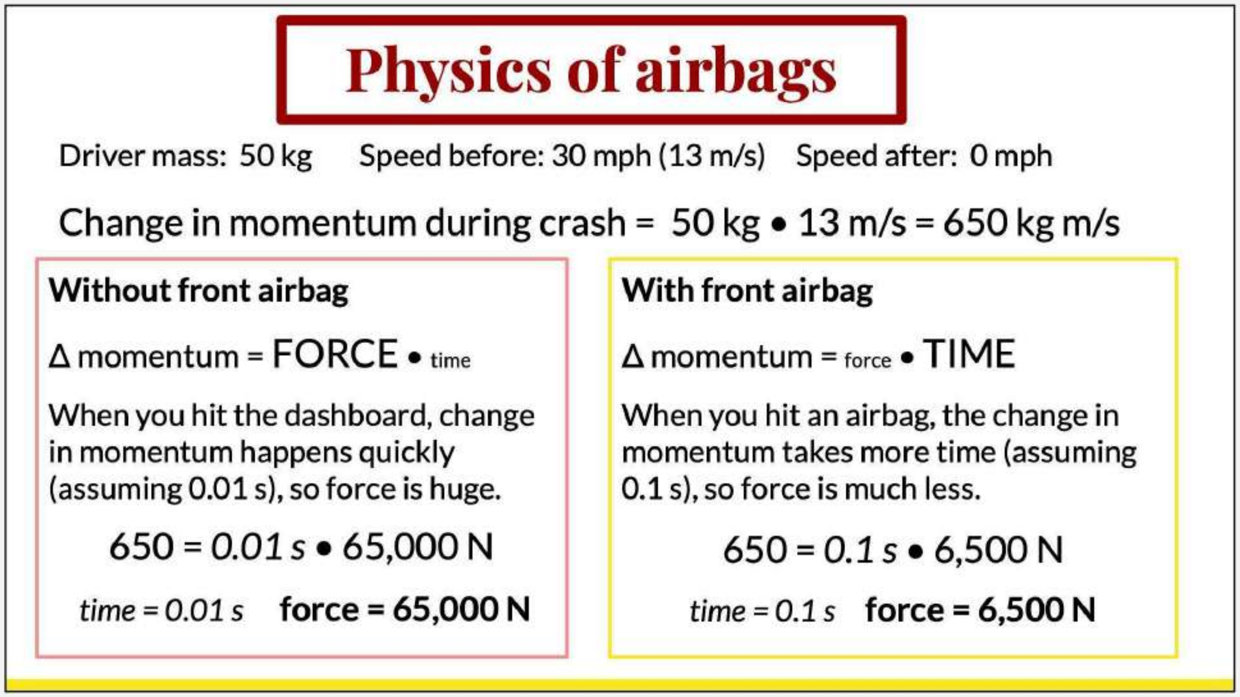
MATERIALS: *Physics Models Used in Design Solutions* (optional)

Remind students of how we ended last class and where we're going next. Present **slide Q** and say, *Last class, you gave each other some suggestions on which physics models might be useful for explaining why your problem is dangerous or why your solution makes things better. Today we're going to go much deeper into that question, and you'll apply the physics models you develop to help you present your solution.*

Ask students to consider questions about approximating reasonable values for our models. Say, *How might we come up with valid assumptions and approximations for our models? How can we tell if an approximated value in our model is valid or reasonable?*

Look for answers such as these:

- We could try to look up values.
- We could make measurements ourselves if we had the right equipment.
- A value is unreasonable if it doesn't make any sense.
- Reasonable values aren't too big or too small, but they're not necessarily exactly right either.
- "Pretty close" is usually good enough when you're approximating.



Ask students to consider if values used in an example model are reliable or valid. Present **slide R**. If you think it will help students, pass out to each group one copy of *Physics Models Used in Design Solutions* on paper and ask students to focus on the "Physics of airbags" example.

Ask students to study the example model of a crash with and without an airbag. Say, *Which values seem valid or reasonable? Which don't? Why do you think so?*

Look for answers such as these:

- For a person, 50 kg is a reasonable mass, and 30 mph is a reasonable driving speed.
- The number 650 is calculated from other values, so it's only reliable if the other values are.
- It makes sense that the airbag time interval is longer than without an airbag.
- It makes sense that the person feels less force with an airbag--that's what makes it safer.
- The number 650,000 N seems like a huge amount, but I don't know if that's reasonable.
- The number 6,500 seems like a lot, but I don't know if it's too much.

Reassure students that it's often quite challenging to come up with good approximations. Say, *Many of us are going to have a hard time approximating anything close to exact values, but this is true for real science work a lot of the time. Modeling can be really useful if the values are even sort of close, especially if we're able to see a useful difference between two values. In this case, it helps us understand part of why airbags are safer to see these two force values next to each other--one is obviously smaller and safer than the other.*

ALTERNATE ACTIVITY	It may help students who are struggling to make the physics modeling more concrete by showing them an example that pertains more closely to models that have relevance for their chosen problem or solution. For these purposes, use *Physics Models Used in Design Solutions*.

13 · APPLY PHYSICS MODELS TO OUR PROBLEMS OR SOLUTIONS

18 min

MATERIALS: *Design Challenge Organizer*, computer with access to https://s3.amazonaws.com/p.3simulation/collisions/sandbox.html (optional), posters developed throughout the unit (see Materials Preparation)

Direct students' attention to modeling their own problem and/or solution. Return any copies of the *Design Challenge Organizer* to students, with feedback and suggestions written. Present **slide S** and ask students to consider with their group what models will be most useful. Point to the posters showing physics models developed throughout the unit and say, *We've developed quite a strong understanding of these various modeling tools in these posters. Now it's time to put those models to work and think through how physics can save lives!*

After some time has elapsed, many groups will likely have questions about how to choose values for their computational models. As you circulate from group to group, try to get a sense from the class of when would be a good time to focus their attention on choosing specific values.

Suggest methods students can use to choose values that make their modeling more reliable. Present **slide T** and say, *On the slide you'll see a few methods--A through D--that you might use to choose values for your model. Talk with your team about which of these methods could be most useful for your problem or solution. You may need to try a couple of different methods before you find something that works.*

ALTERNATE ACTIVITY	For groups that want to go deeper by experimenting or examining data, provide the link to the sandbox version of the simulation (https://s3.amazonaws.com/p.3simulation/collisions/sandbox.html). Students can use this to inform their design solutions and make direct connections with the physics models.

ASSESSMENT OPPORTUNITY	**14.C.2 What to look/listen for in the moment:** Look for students to do the following: • Refer to question 2 for background and use the models we have developed and displayed on

posters in the room to work through specific, quantitative details about their problem or their solution. (SEP 2.6)

- Acknowledge that there are limitations to the calculations they can make in their model because of assumptions and approximations they make. If necessary, students will make up reasonable approximations or research related values that help support the case for their solution. (CCC 4.4)
- Focus their attention on factors related to the criteria they identified in question 4 and target both their modeling and their solutions around these criteria. (ETS1.C.1)

What to do: Refer to *Design Challenge Organizer Key* for detailed guidance on how to give targeted feedback.

Building toward: 14.C.2 Use reasonable assumptions or approximations to develop a mathematical model to generate data to predict behavior of a design solution, analyze a system or support an explanation, and meet prioritized criteria. (SEP 2.6, CCC 4.4, ETS1.C.1)

14 · COMPILE WORK INTO A FINAL PRODUCT

18 min

MATERIALS: *Design Challenge Organizer*, *Final Product Example Summary*, https://docs.google.com/presentation/d/1oOonZVXDajELVudwtdUuDT97C5H8xPNC5amy8bFH32O/copy

Alert students to necessary sections of their Final Product. Present **slide U** and ask students to turn to question 7 in the *Design Challenge Organizer*. Emphasize that they have flexibility in the format that they choose to use in their Final Product, but the content of the work they present should reflect the thinking they've already done over the past three class days. Say, *If your team has been staying on track these past few days, making this Final Product may not involve much new thinking. Look closely at each team member's written work in questions 2, 3, 4, 5, and 6. Feel free to pick and choose the best parts of each person's work or answer to summarize for your Final Product.*

It may help some students to see examples of Final Product slide decks; these examples are shown in https://docs.google.com/presentation/d/1oOonZVXDajELVudwtdUuDT97C5H8xPNC5amy8bFH32O/copy. Students may benefit from spending more time finding supporting evidence about cause and effect and other factors (to accompany their prioritized criteria) or useful values or relationships (to accompany their physics models).

Encourage students to get more feedback from their peers individually. Halfway through the allotted work time, present **slide V**. Encourage groups to assign one student from their group to pair up with a student from another group, exchange TAG feedback, and report this feedback back to their group. Say, *As you work it will be useful to get quick feedback from other groups thinking about different problems. Send one* *representative from your group to pair up with someone from another group, and exchange TAG feedback about a specific section of your work. Tell something you like, Ask a question, Give a suggestion for improvement.*

ALTERNATE ACTIVITY	It is unlikely that all groups will have enough time to complete their Final Product in the same amount of class time. Consider giving written feedback outside class on their work so far and assigning the rest of the Final Product for home learning or providing students with an extra class day. If time allows, consider giving students a chance to present their work more formally to one another, using a co-created rubric to evaluate one another's work. As a class, students might identify the solutions with the most potential to impact change and provide suggestions for how to advocate for these solutions (city hall, parent groups, etc.).

15 · NAVIGATE

3 min

MATERIALS: None

Forecast the assessment opportunity in Lesson 15. Present **slide W**. Say, *Wow, we have come a long way in this unit. Not only can we explain the trends we identified on day 1, we can now describe the physics of vehicle collisions in great detail and explain how technology in vehicles works to save lives. We have ideas about how to improve our own community as well, and we understand some of the complex constraints and trade-offs inherent in making decisions that affect people's lives. Next class, we will have the opportunity to demonstrate in an assessment how much we have learned.*

Additional Lesson 14 Teacher Guidance

SUPPORTING STUDENTS IN MAKING CONNECTIONS IN ELA	**CCSS.ELA-LITERACY.RST.11-12.7** Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem.